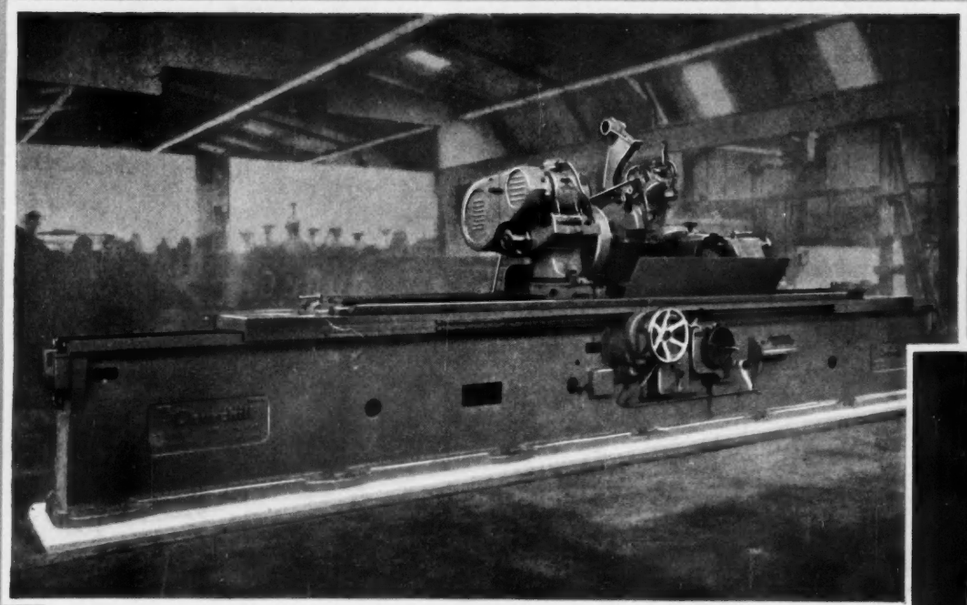
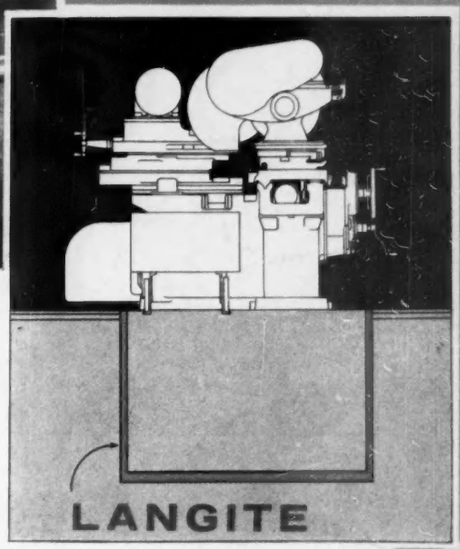
# THE ENGINEER

JANUARY 29, 1960 | 28 ESSEX STREET, STRAND, LONDON, W.C.2 | TWO SHILLINGS





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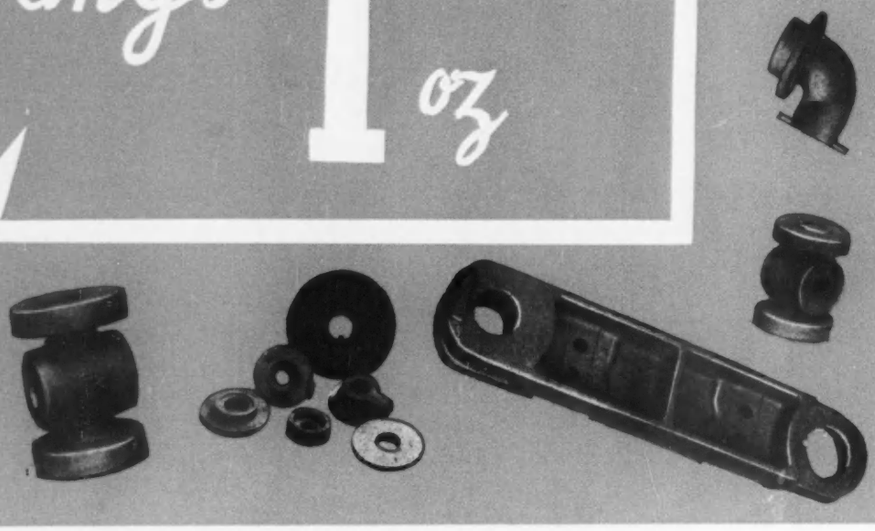
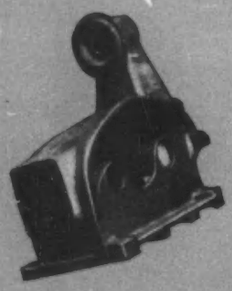


*to* 20 tons



*in...*

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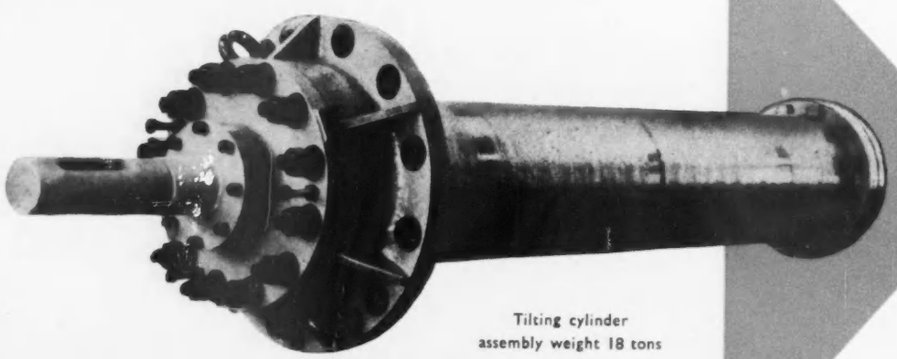

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assembly weight 18 tons

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*Established* 1856

No. 5427 JANUARY 29, 1960 VOL. 209

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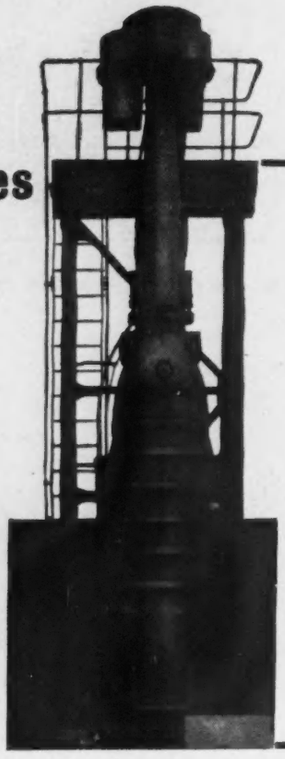

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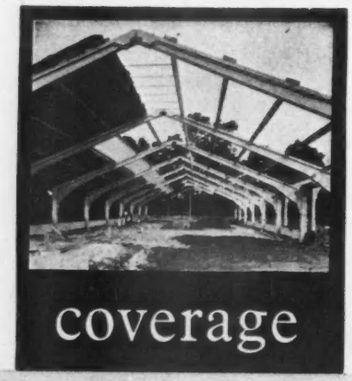

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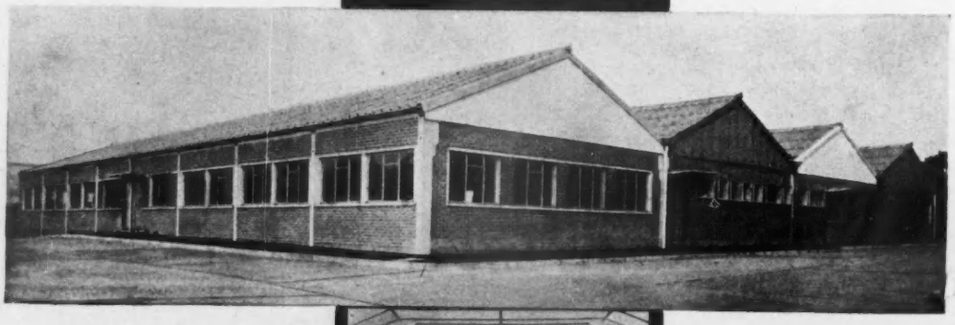

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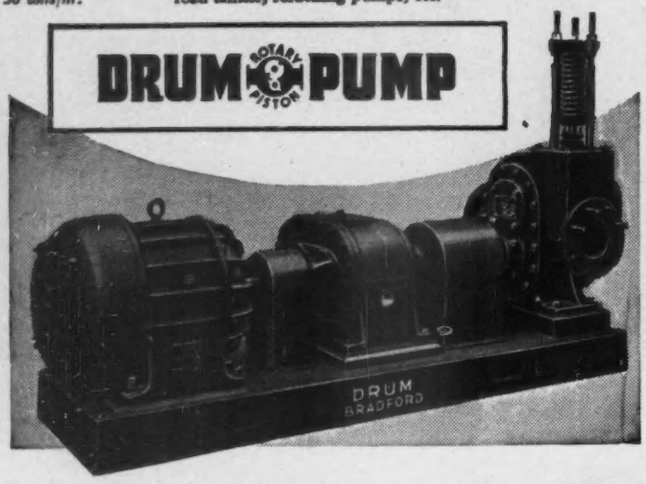


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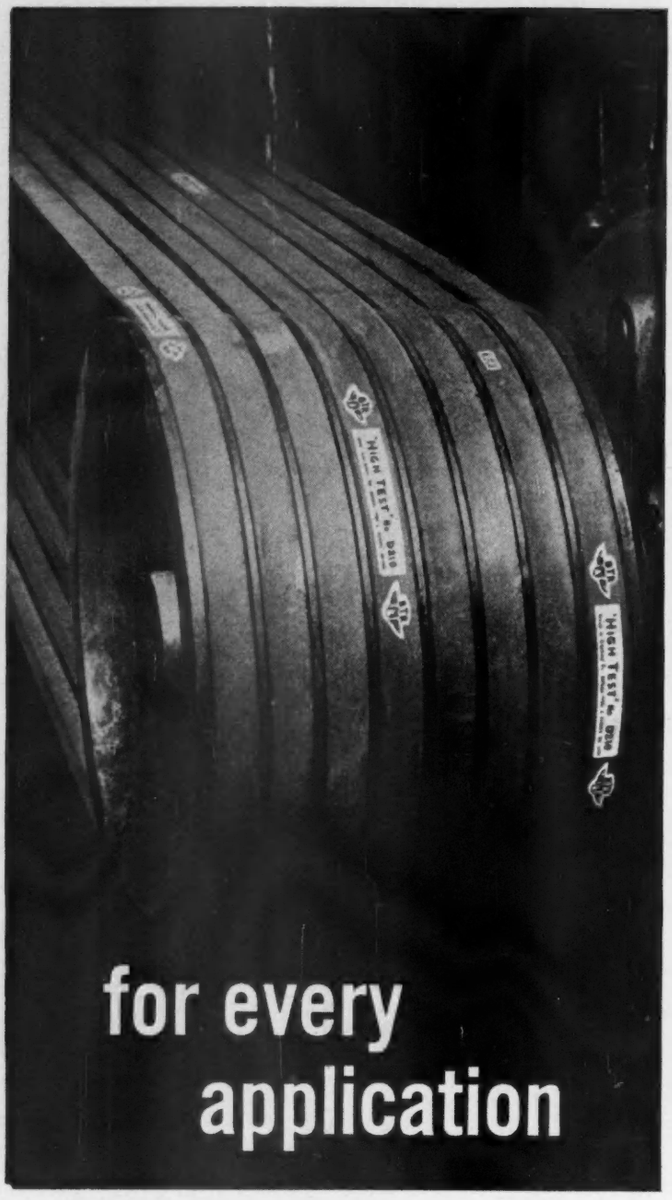


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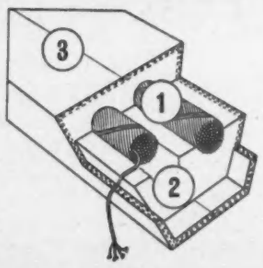


*This diagram shows (1) the load-carrying members (2), the rubber cushion and (3) the 2 ply cover of specially woven wear resisting material of a BTR High Test V-Belt. This Grommet construction is available in Sections B, C, D and E.*

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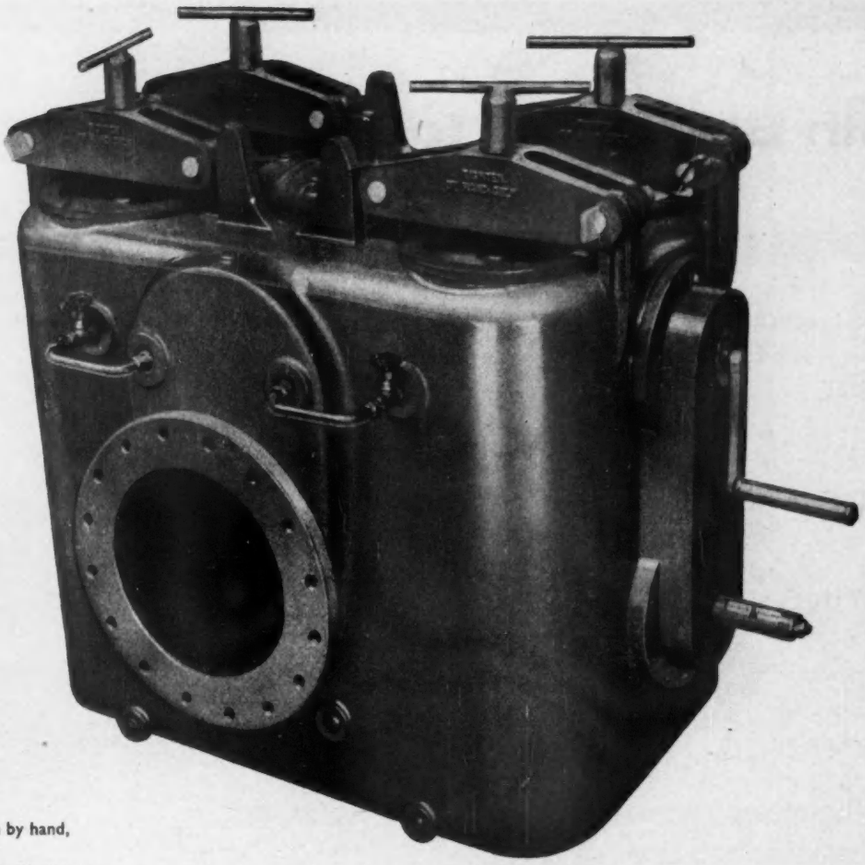

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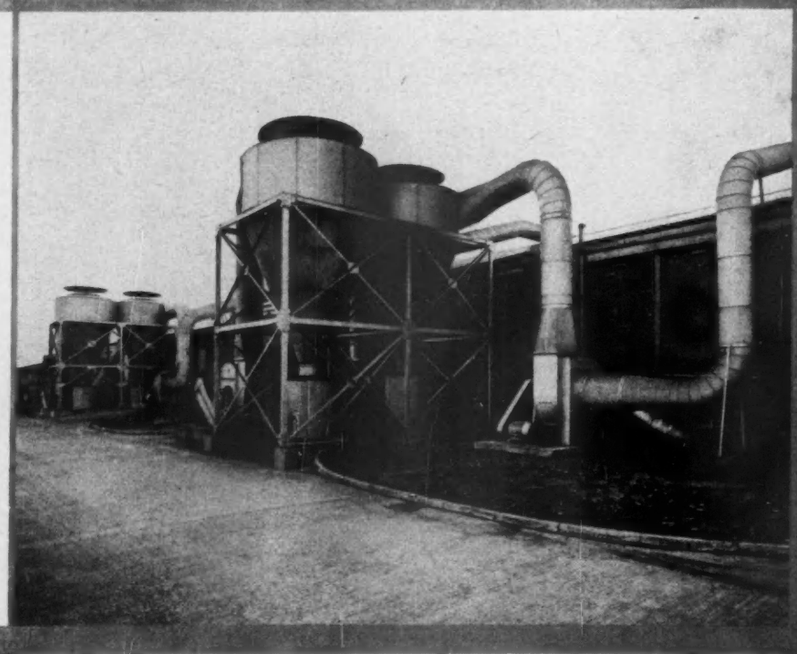

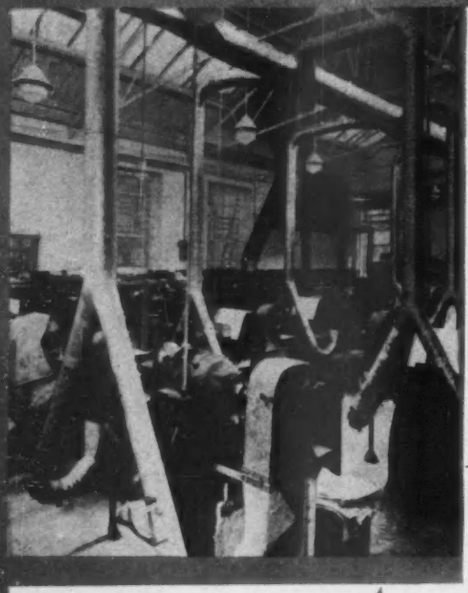

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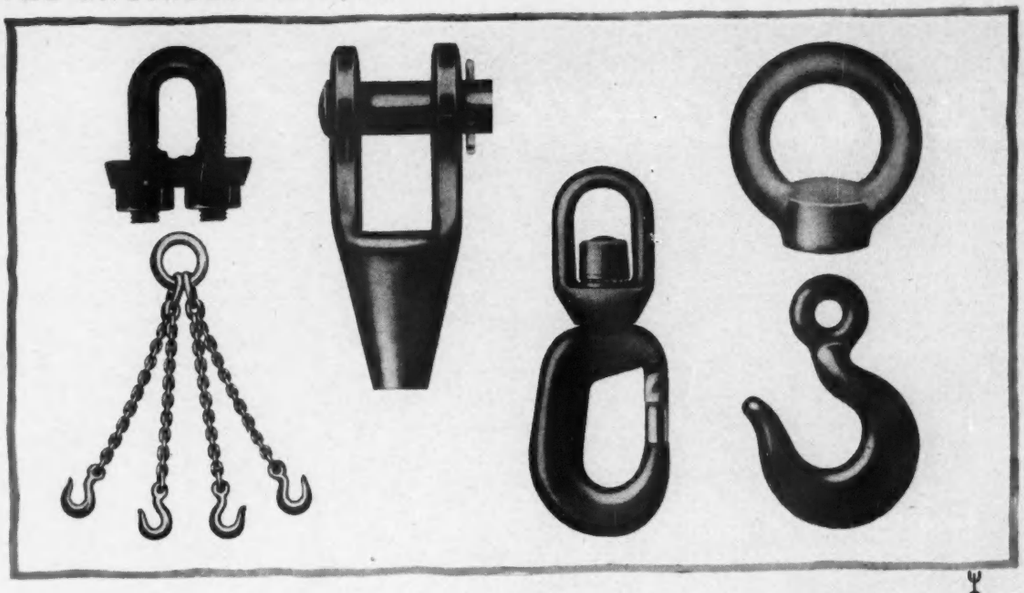

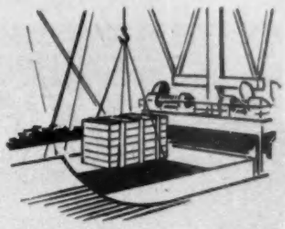

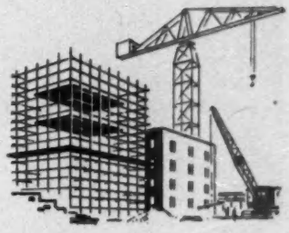

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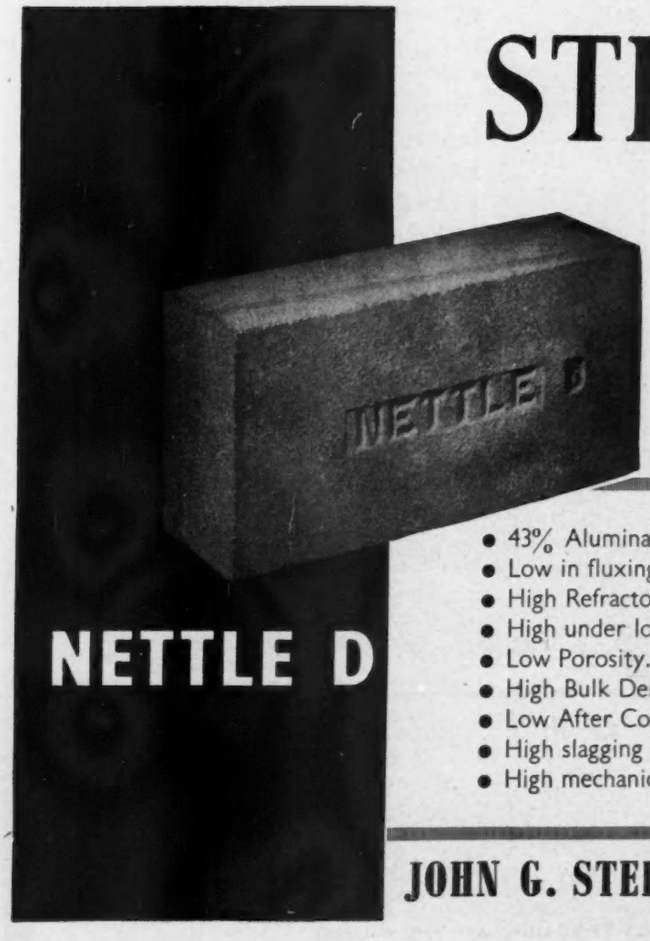


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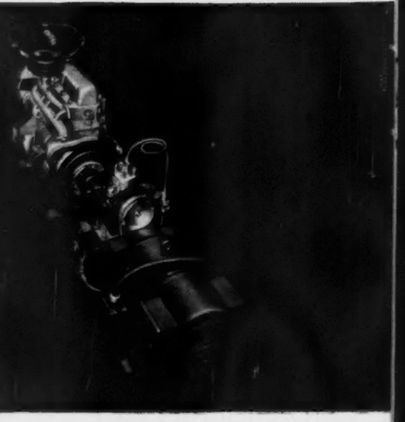

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**ONLY COLES CAN CLAIM :—**

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**(2) THE WIDEST RANGE OF LIFTING CAPACITIES.**

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**(4) CRANE FACTORIES IN FULL PRODUCTION IN GREAT BRITAIN, U.S.A., AUSTRALIA AND WESTERN GERMANY.**

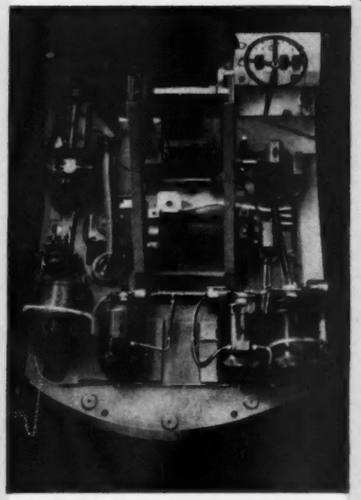
**(5) MORE CRANES IN SERVICE THAN ANY OTHER MAKE OF MOBILE CRANES.**

. . . and over 80 years' experience of the biggest, toughest and most complicated handling jobs is behind the design of Coles new range of Diesel-Electric Cranes ; from Concrete to Air Engines, Coles flexibility counts.

When you use Coles you achieve speed and precision with safety.

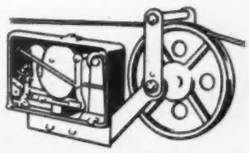
## *UNIT CONSTRUCTION*

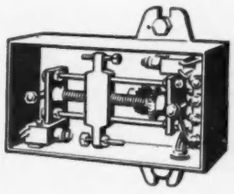
Coles Cranes are designed for maximum work with minimum maintenance ; this clean, simple layout ensures easy maintenance with quickly removable, self-contained, totally-enclosed units. The superstructure base is accurately machined to receive the self-contained units of hoist, derrick and slew motions, power unit and generator. Easily removed panelling gives maximum weather protection and quick accessibility for ease of servicing.

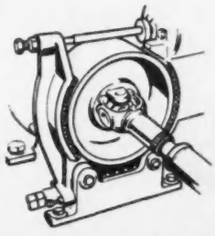


## *FINGER-TIP CONTROL*

After only a few minutes instruction anyone can operate a Coles Crane. Pilot switches and accelerator are grouped together for easy, fatigue-free operation ; every control movement is instinctive, leaving the operator free to concentrate upon signals and his load. Coles finger-tip electric control ensures a fresh, alert operator efficient to the end of the day—a vital safety factor.







## *SAFETY*

Coles many safety devices remove the human element risk and give the operator the security and confidence which enable him to work efficiently under all circumstances. In addition to the visual radius indicator which shows the safe working load, an automatic safe load indicator is fitted to weigh the load at a given radius, also giving the operator visual and audible warning of any tendency to overload—while preventing automatically the lifting of an unsafe load, irrespective of jib positions.

## *PRECISION WITH SPEED*

Coles fast, finger-tip controlled motions provide an infinite range of speeds from zero to maximum. Faster, smoother, safer operation with maximum handling economy is obtained by simple operation of the accelerator pedal.

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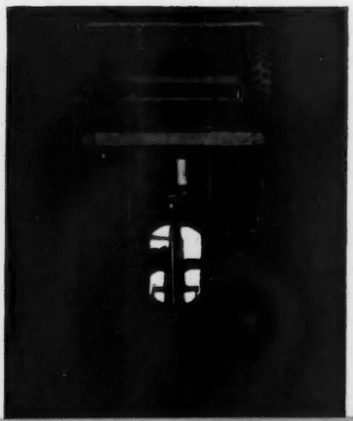
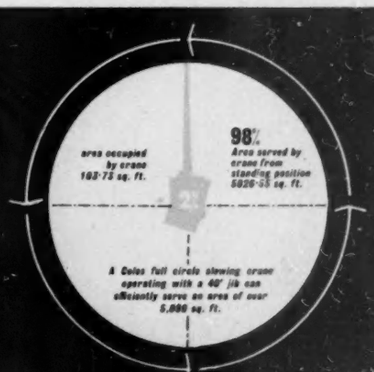


## *EFFORTLESS TRAVEL*

Coles Cranes move fast on the road and are designed for swift, easy movement from job to job, under all operating conditions ; built specially to withstand the heavy stresses and shock loadings unavoidable on Crane duties. Our road travel experience is greater than any other European Manufacturer, let us pass this on to you.

## *FULL-CIRCLE SLEWING*

The operator, situated on the front of the full-circle-slewing superstructure, can place the hook in any position within a circle, having a radius equally the length of the jib ; he can reverse the motion and slew in the opposite direction without limit.


area occupied by crane 103·75 sq. ft.
98%
Area served by crane from standing position 5026·55 sq. ft.
A Coles full circle slewing crane operating with a 40' jib can efficiently serve an area of over 5,000 sq. ft.

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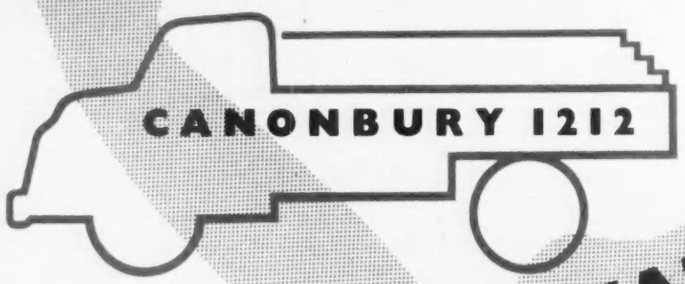


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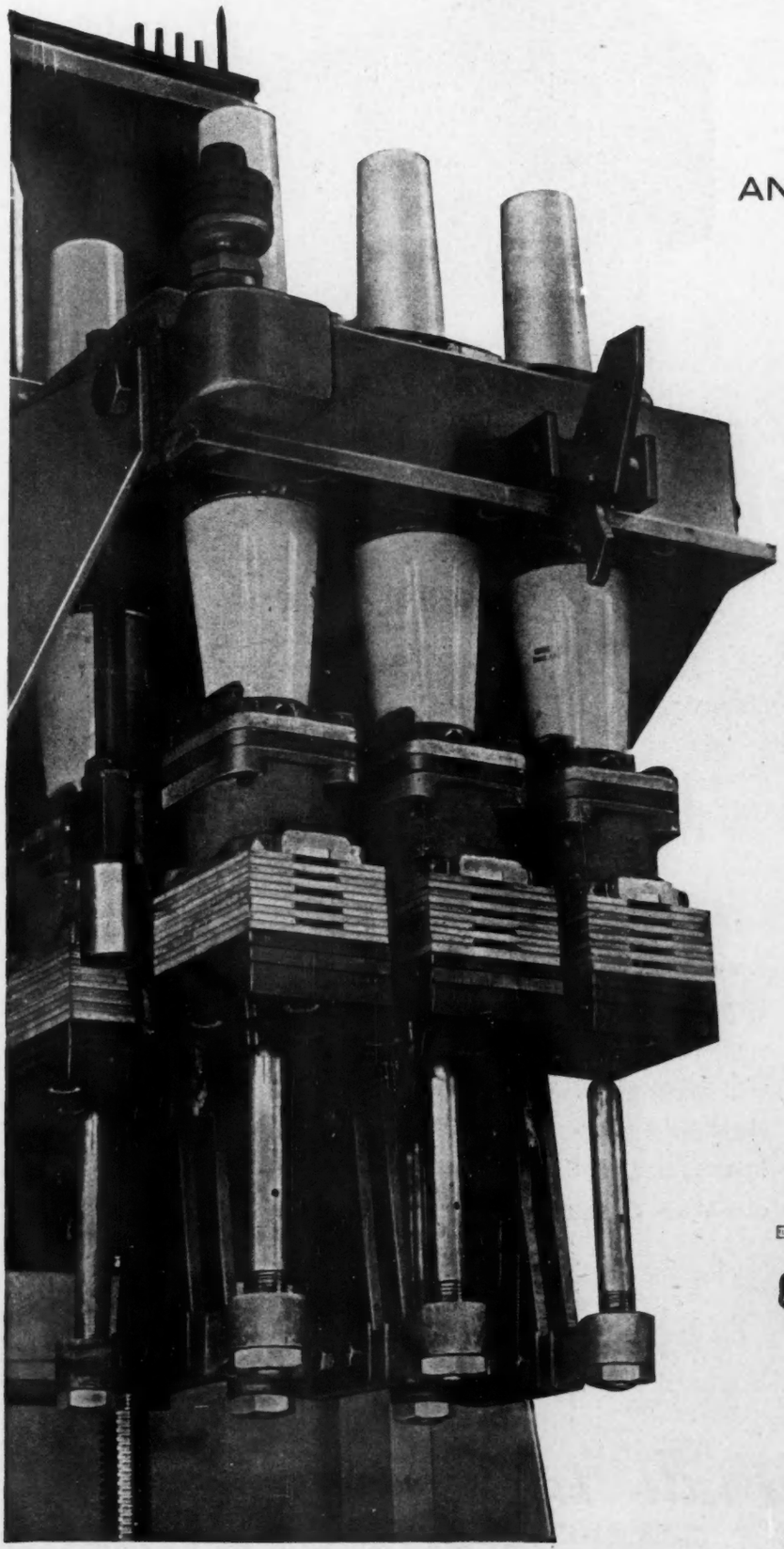

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You, as an engineer, know that there can be no sharp dividing line between designing and building. A good design incorporates experience gained in making, testing and installing similar equipment in the past. And, of course, it is also shaped by the experience of all sorts of people using the earlier designs under a variety of conditions that could not be simulated in any test laboratory.

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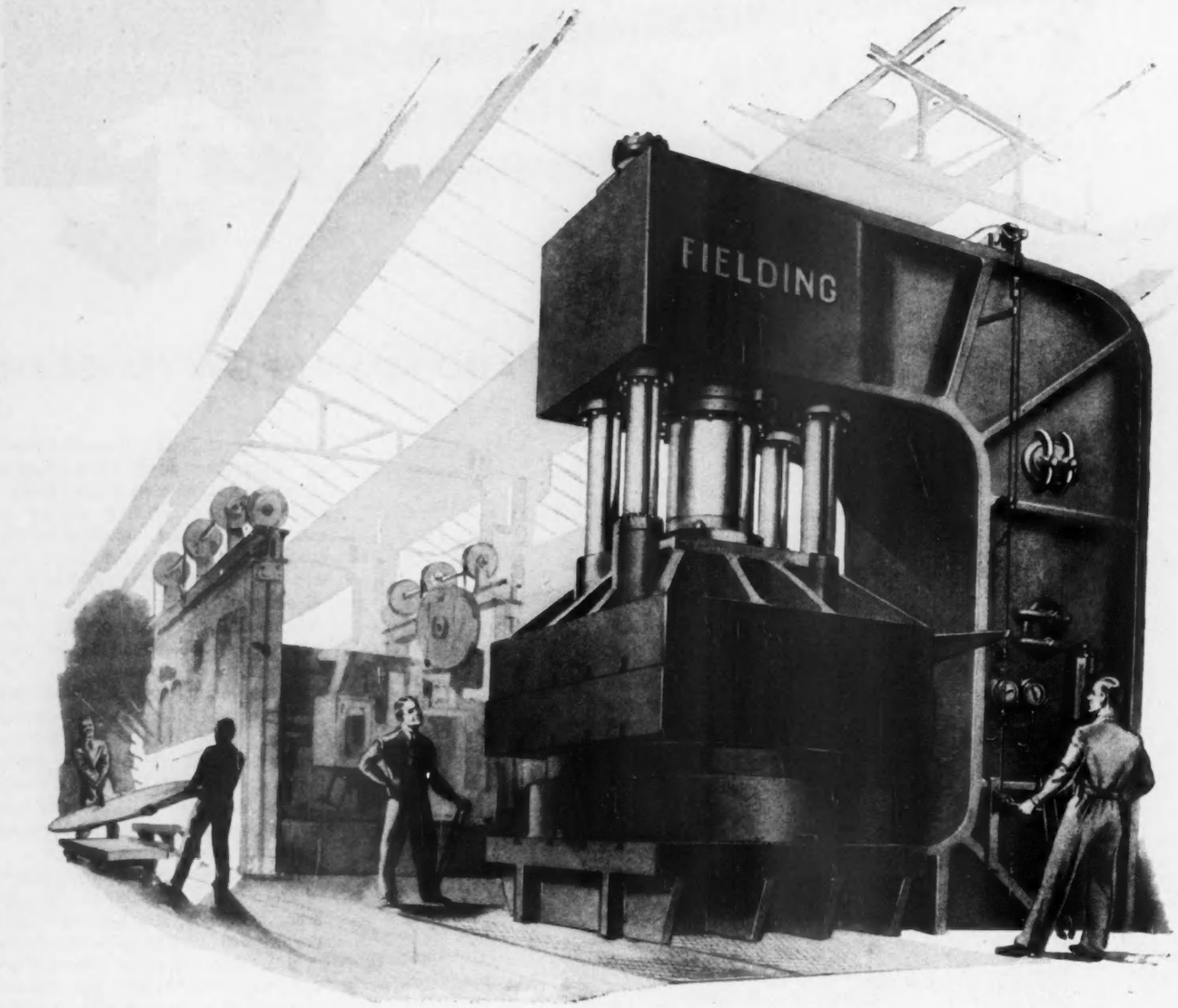


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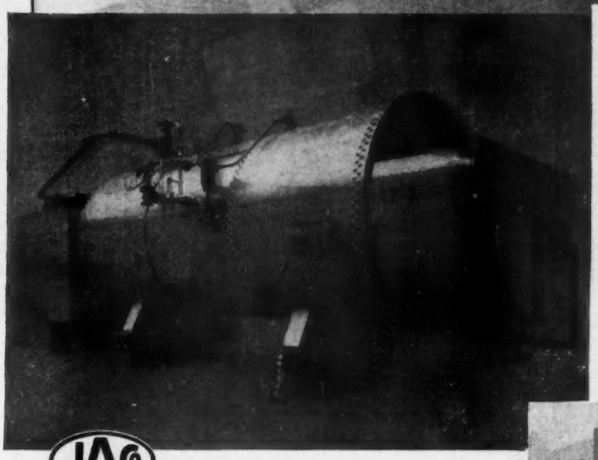
# JOSEPH ADAMSON
## *Waste Heat Boilers*



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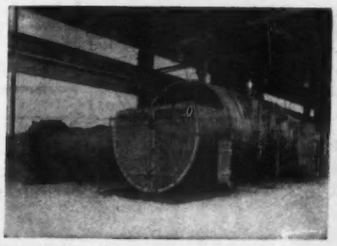
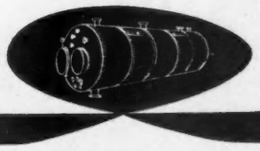


The Joseph Adamson Waste Heat Boiler is designed to make efficient use of the waste gases leaving open-hearth furnaces, reheating furnaces, soaking pits, gas retorts, etc.

The straight-through fire tubes have a high ratio of length to bore, giving about 90% tube efficiency and providing a large area of heating surface in a comparatively small space. Brickwork setting is not required and air infiltration is thus avoided.

A feature of Joseph Adamson Waste Heat Boilers is that a special cleaning device can be provided in the outlet chamber to allow the tubes to be cleaned while the boiler is at work.



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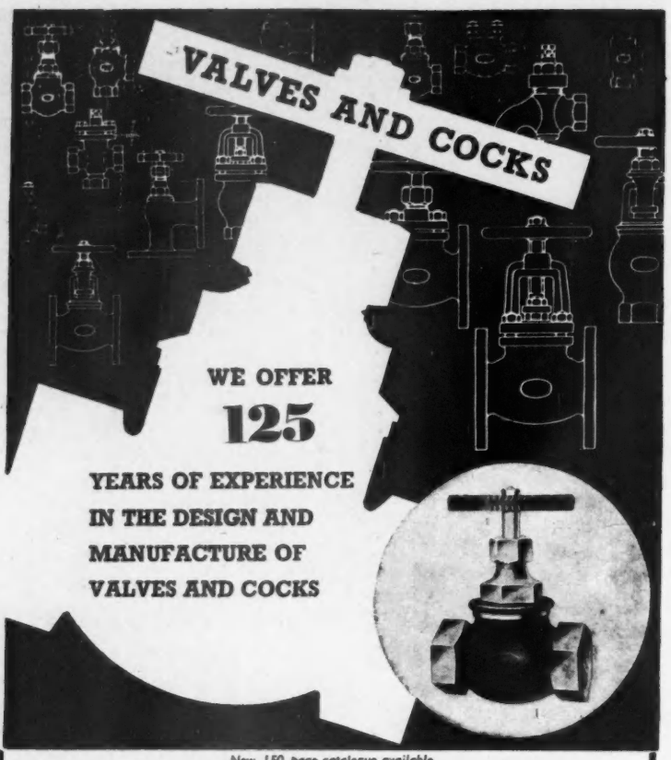


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Large illustration shows a Shipham casting for a Centrifugal Pump Cover —overall length 4′ 0″; weight 1330 lbs. Alongside—Centrifugal Pump Body — overall length 4′0″; weight 2425 lbs.

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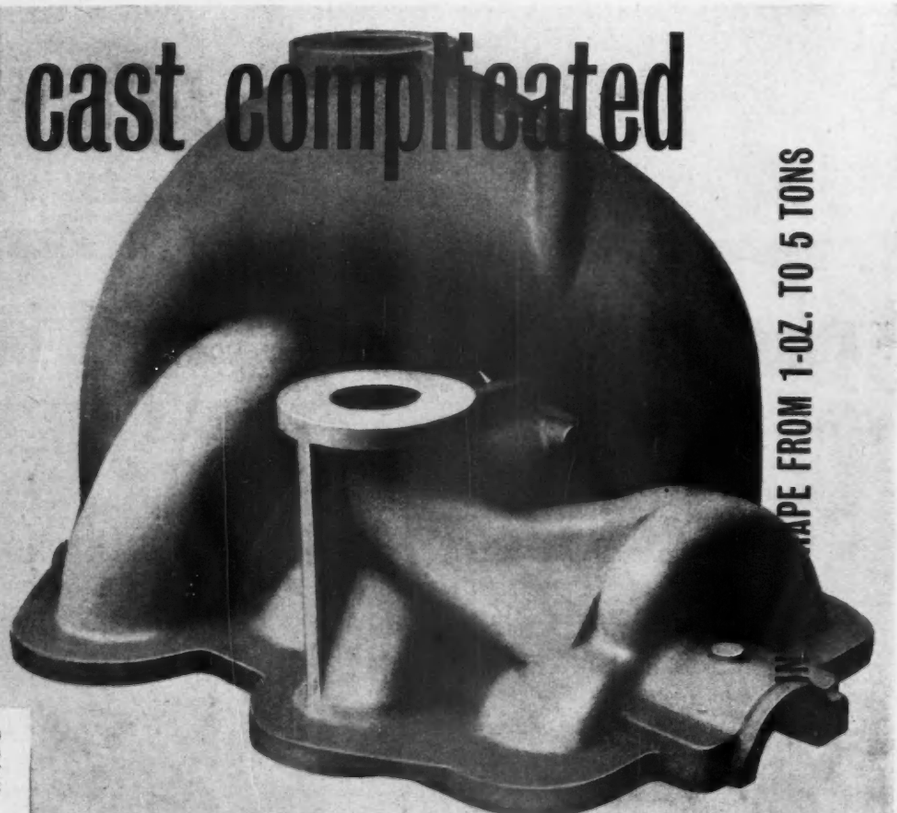

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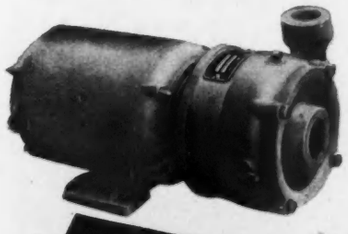

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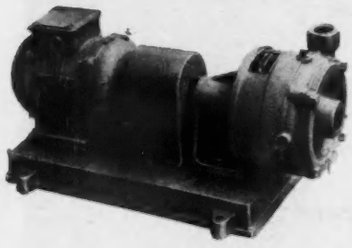
**'Seal' CENTRIFUGAL PUMPS**



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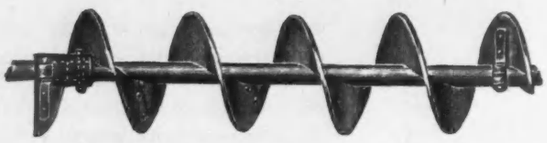

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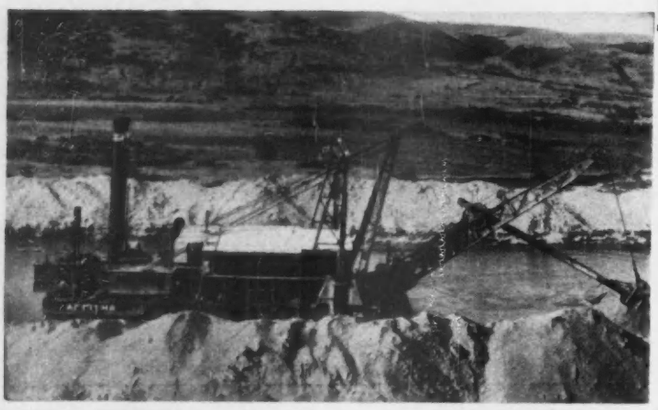

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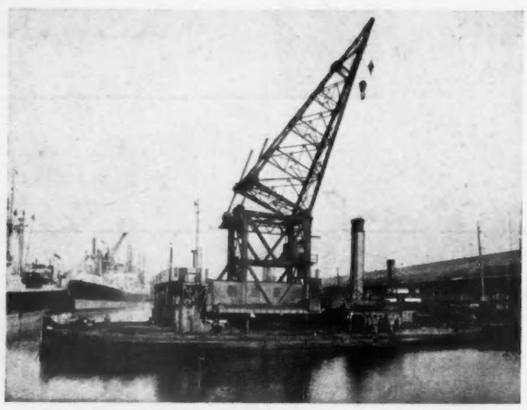

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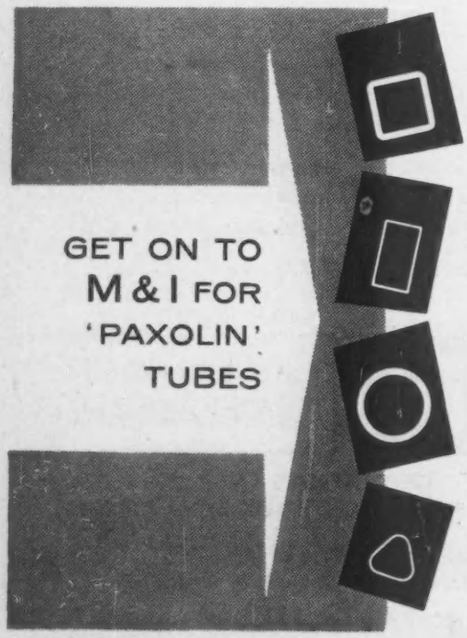

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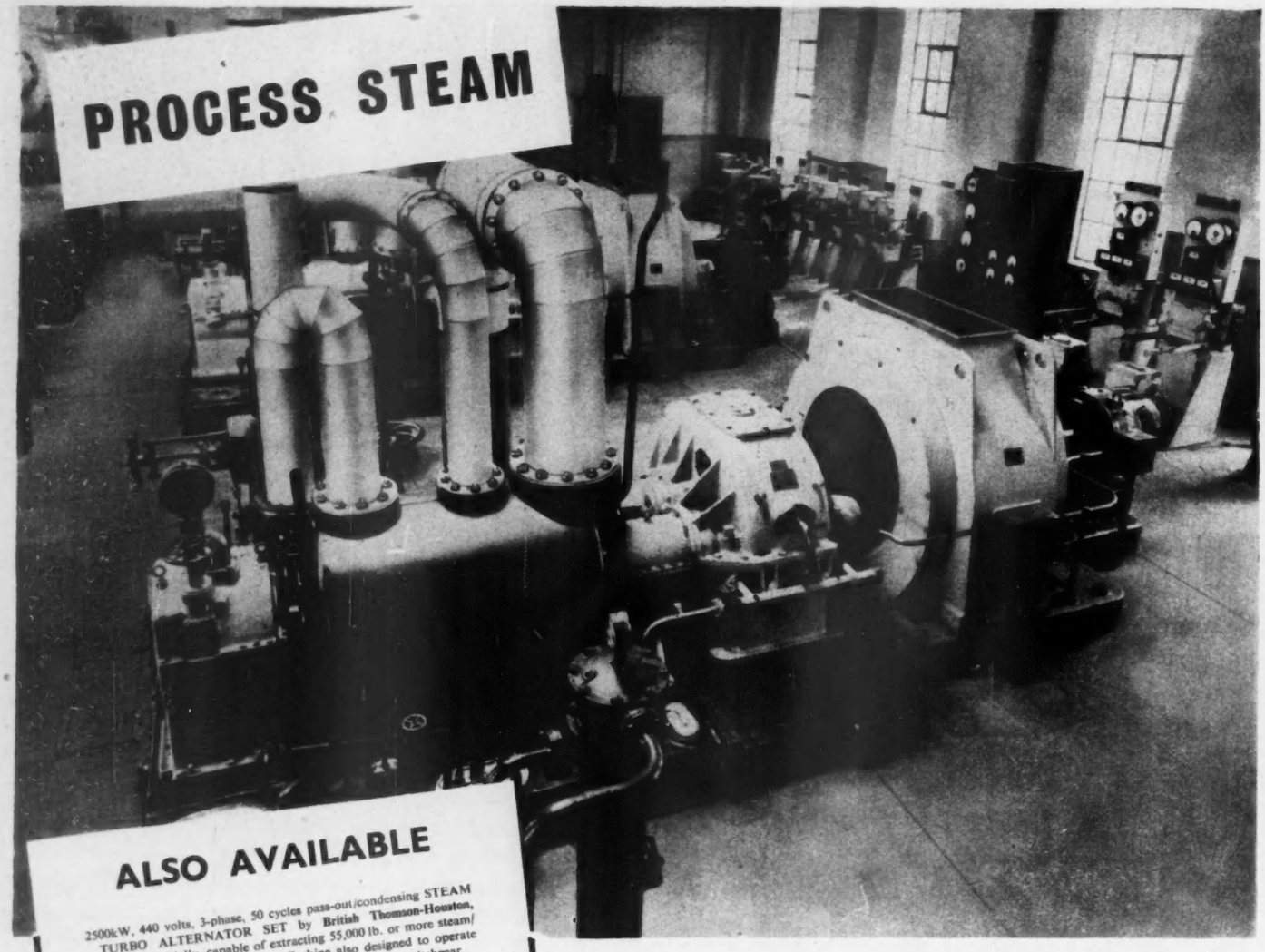

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2500kW, 440 volts, 3-phase, 50 cycles pass-out/condensing STEAM TURBO ALTERNATOR SET by **British Thomson-Houston,** 255 p.s.i. initially, capable of extracting 55,000 lb. or more steam/hour at pressures up to 35 lb. Turbine also designed to operate fully condensing and is complete with ancillaries and switchgear.

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750kW, 400 volts, 3-phase, 50 cycles back pressure type STEAM TURBO ALTERNATOR SET by **Metropolitan-Vickers,** incorporating turbine designed to work with steam at 485 p.s.i., 550 deg. Fah. temperature, exhausting to back pressures between 25 lb. and 60 lb. Direct coupled to alternator, complete with switchgear.

NEW 500kW geared back pressure type STEAM TURBO ALTERNATOR SET by **Metropolitan-Vickers,** incorporating turbine designed to work with steam at 510 p.s.i. initially, 800 deg. Fah. temperature, exhausting against 170/185 p.s.i. back pressure. Direct coupled through gearbox to alternator wound for 400/440 volts, 3-phase, 50 cycles supply, 1500 r.p.m., with exciter and switchgear.

500kW back pressure type STEAM TURBO ALTERNATOR SET by **British Thomson-Houston,** incorporating turbine designed to operate with steam at 300 p.s.i., 150 deg. Fah. superheat, exhausting against 60 lb. back pressure. Direct coupled at 3000 r.p.m. to alternator wound for 400 volts, 3-phase, 50 cycles supply, with exciter and switchgear.

300kW, 375kVA, 400/440 volts, 3-phase, 50 cycles, 4-wire STEAM ENGINE DRIVEN ALTERNATOR SET incorporating compound engine by **Belliss & Morcom,** with h.p. cylinder 19in. bore, l.p. cylinder 25½in. bore by 12in. stroke. Engine arranged to work with steam at 140 p.s.i., 450 deg. Fah. temperature exhausting to back pressures up to 25 lb. Direct coupled to alternator by **English Electric Co.,** with exciter and switchgear.

250kW, 400 volts, 3-phase, 50 cycles STEAM ENGINE DRIVEN ALTERNATOR SET, mounted on cast iron baseplate and direct coupled at 375 r.p.m., comprising compound engine by **Belliss & Morcom,** with h.p. cylinder 15½in. bore, l.p. cylinder 23in. bore by 11in. stroke. Engine arranged to work with steam at 150 p.s.i., dry saturated, exhausting against 15 lb. back pressure. Direct coupled to alternator by **Mather & Platt,** with exciter and switchgear.

TWO 1000 kW back pressure type STEAM TURBO ALTERNATOR SETS incorporating turbines by **Belliss & Morcom,** designed for a steam pressure of 195 lb./sq. in. and suitable for exhausting against 15/20 lb. back pressure. The turbines direct coupled through gearbox by **David Brown,** ratio 4·5 : 1, to alternators by **Harland Engineering Co.,** 1250 kVA, 0·8 p.f., wound for 3·3 kV, 3 phase, 50 cycles, star connected 1000 r.p.m. with direct coupled exciter. Complete with control gear and automatic voltage regulator.

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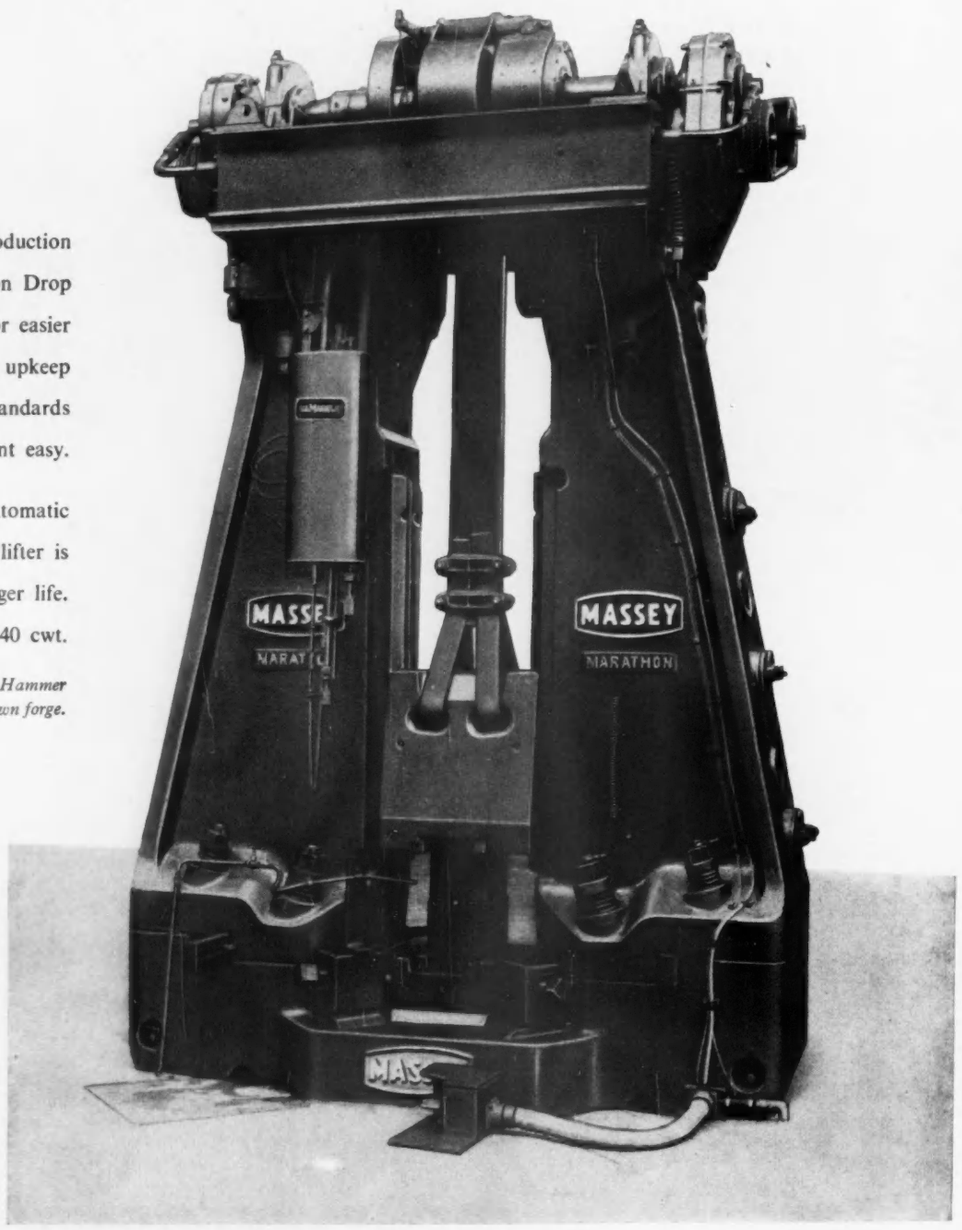


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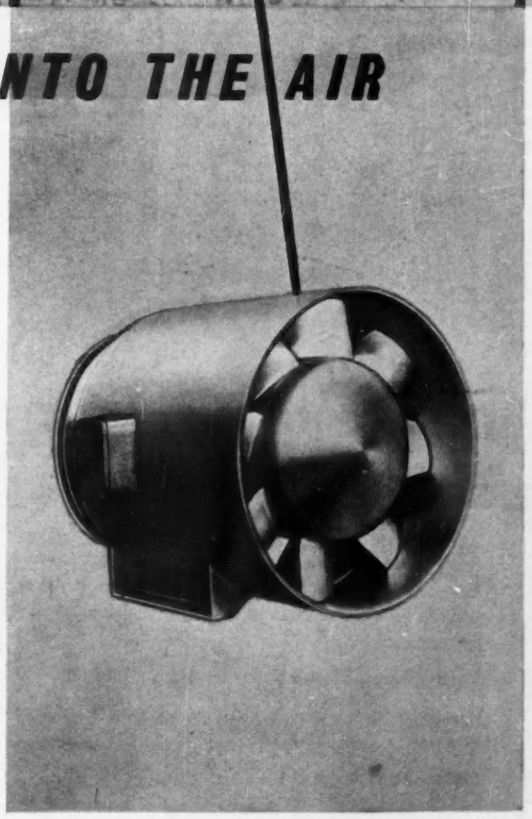

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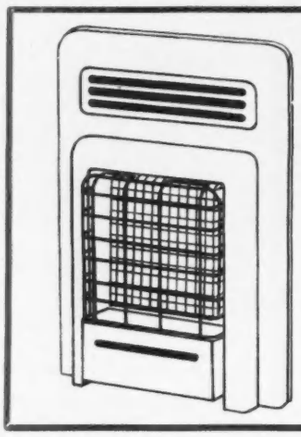

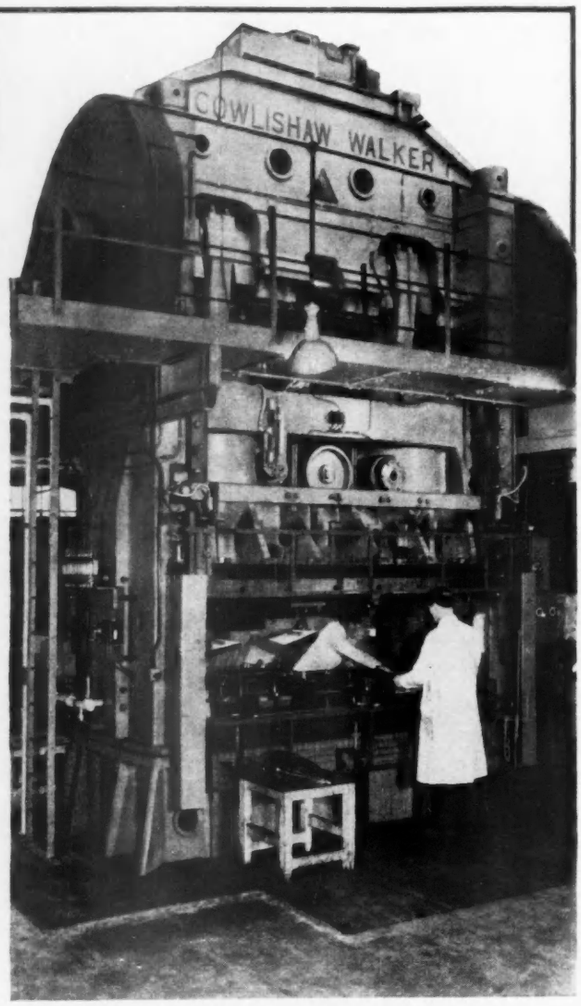


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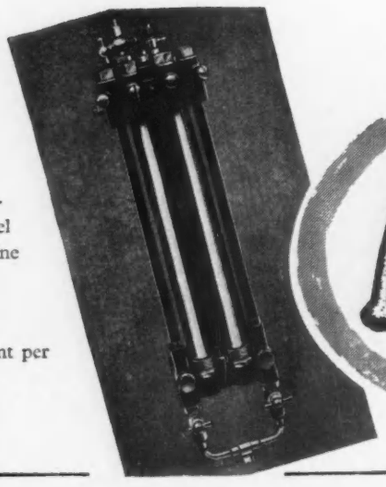

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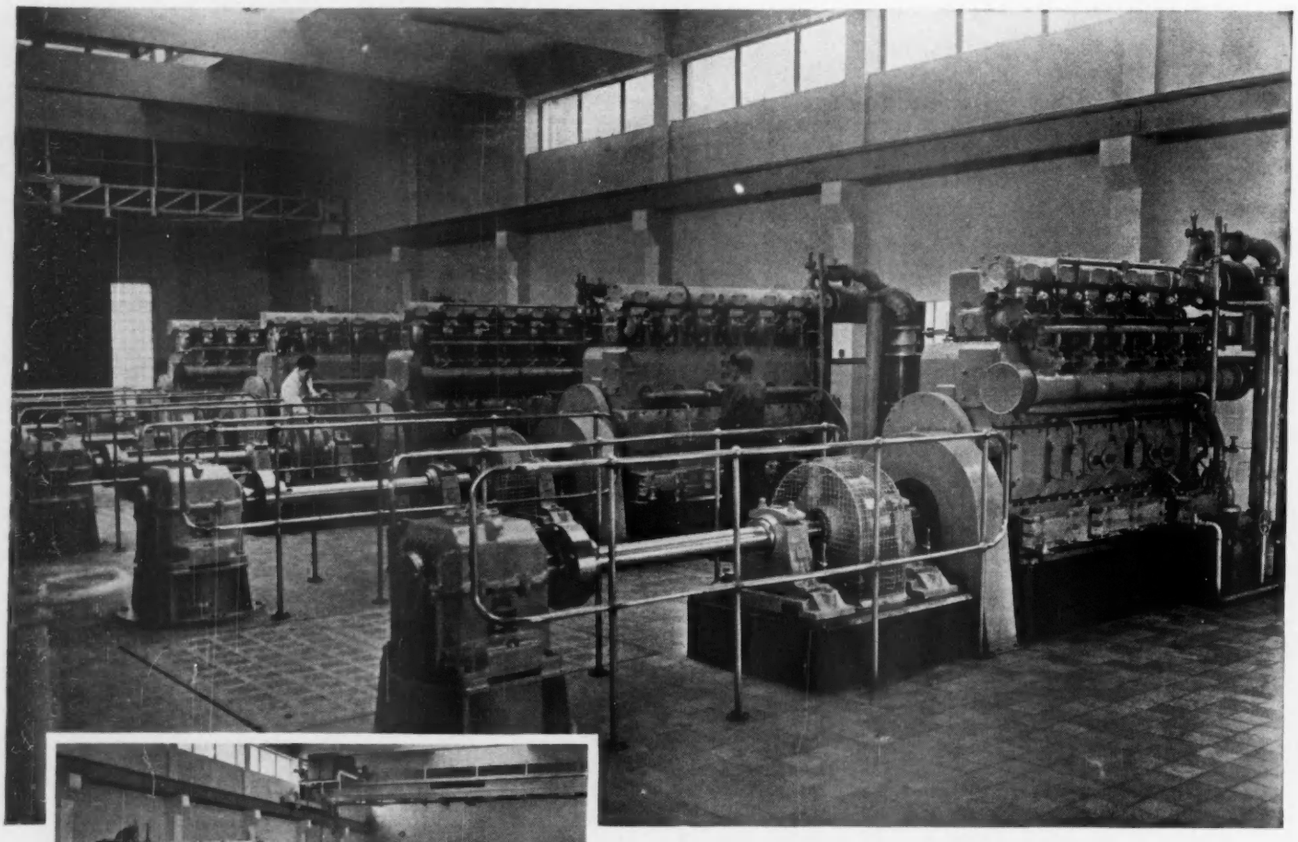

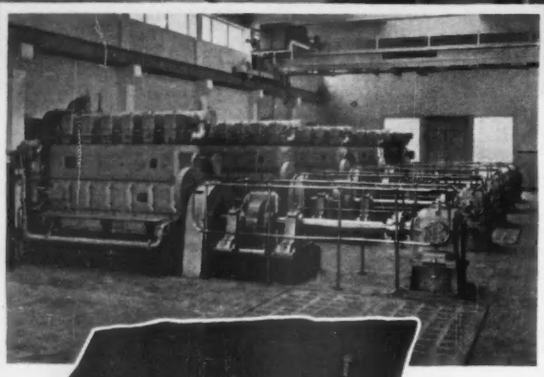

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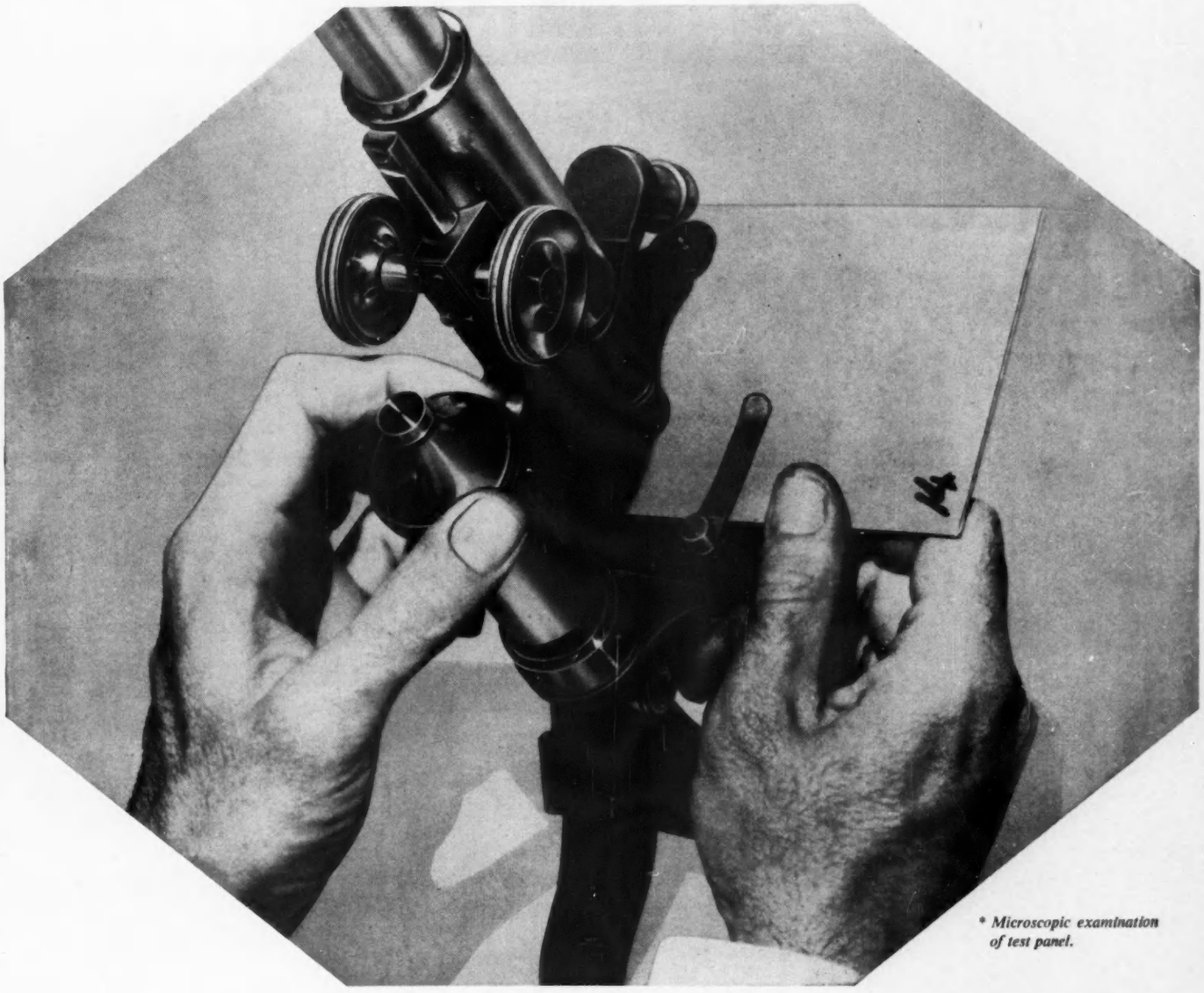

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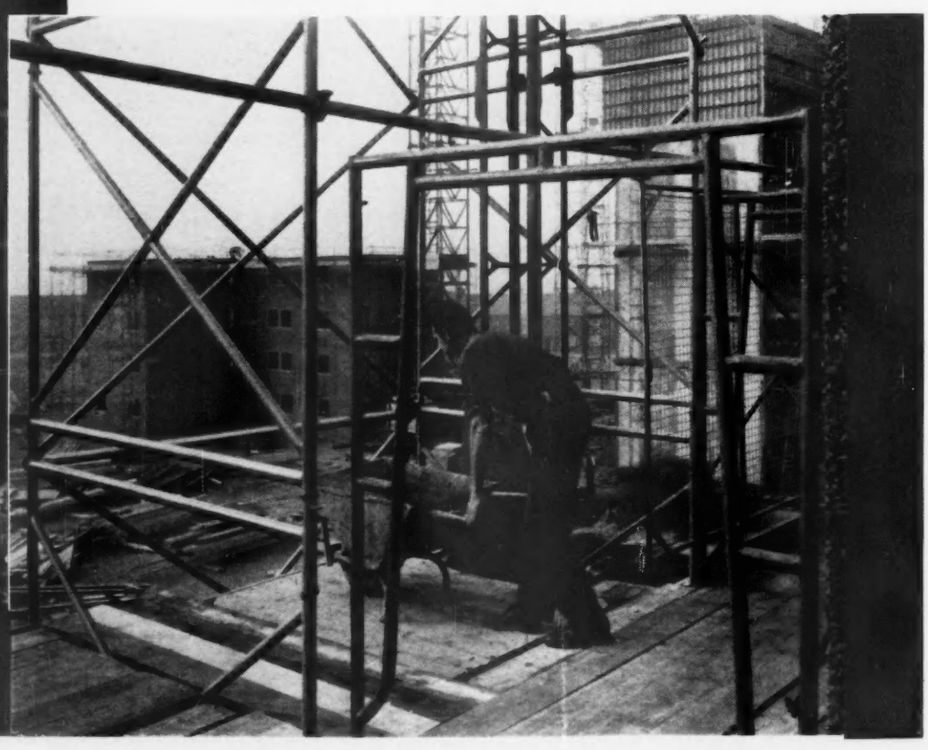

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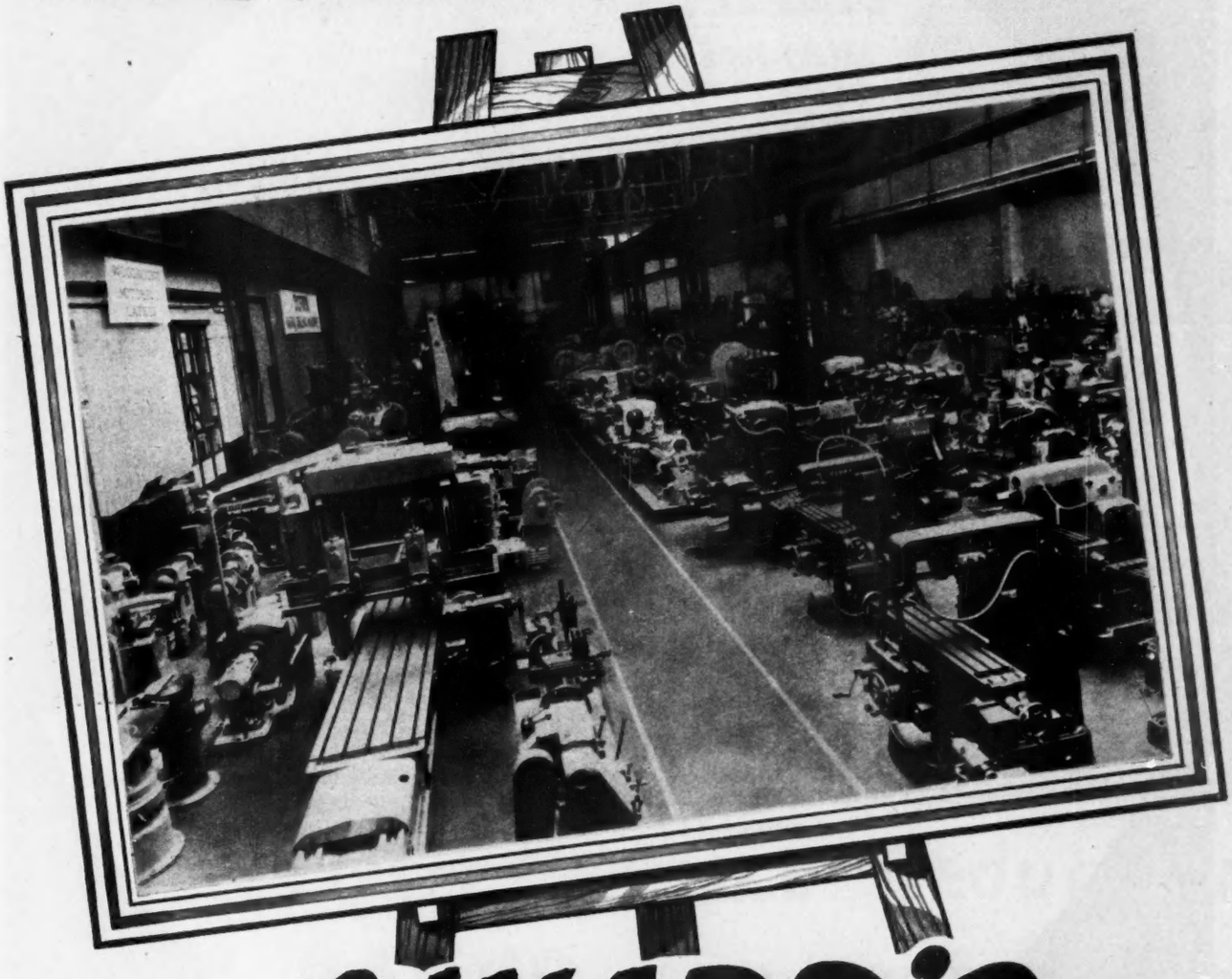
# An Exhibition in itself....



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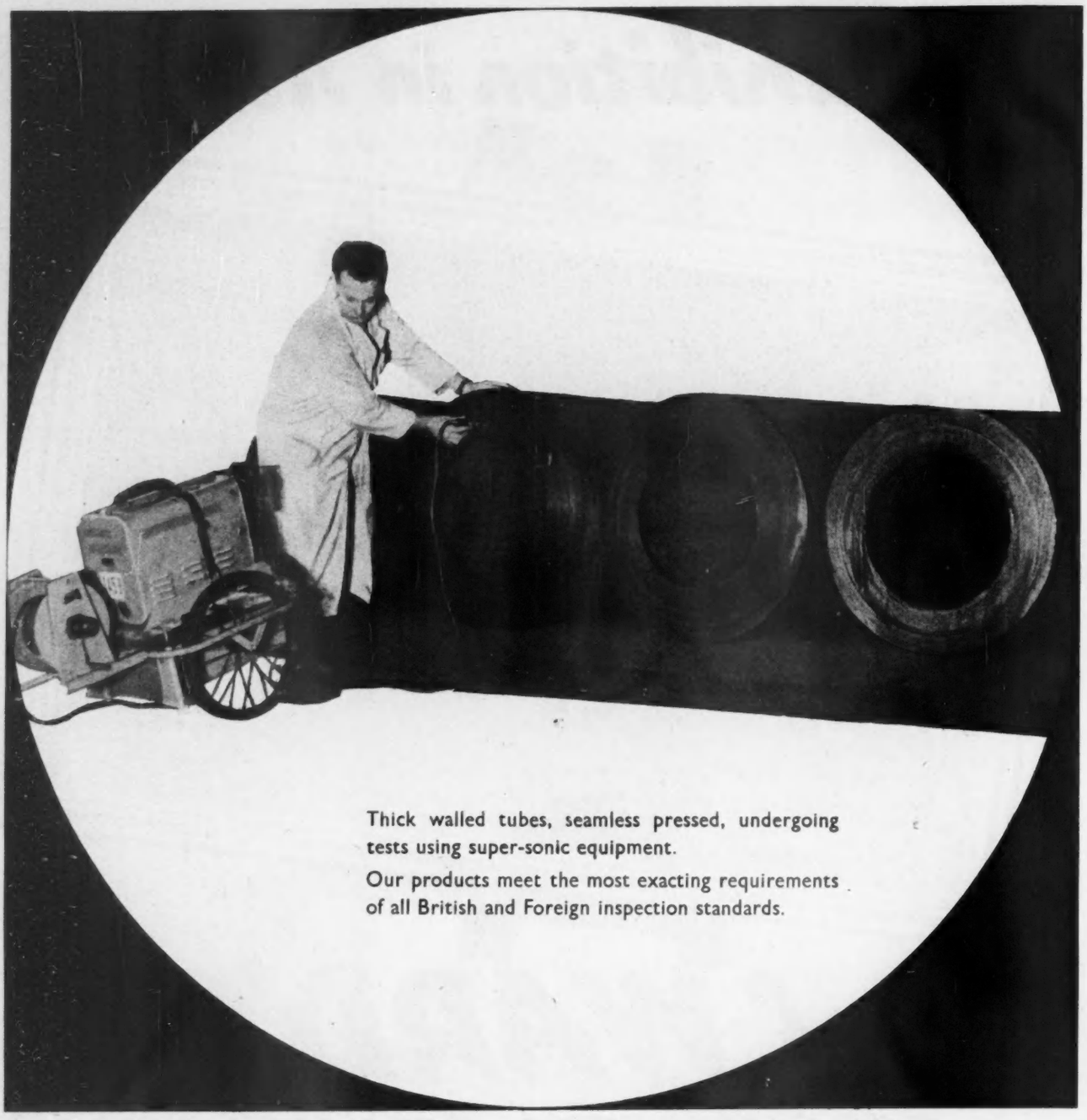

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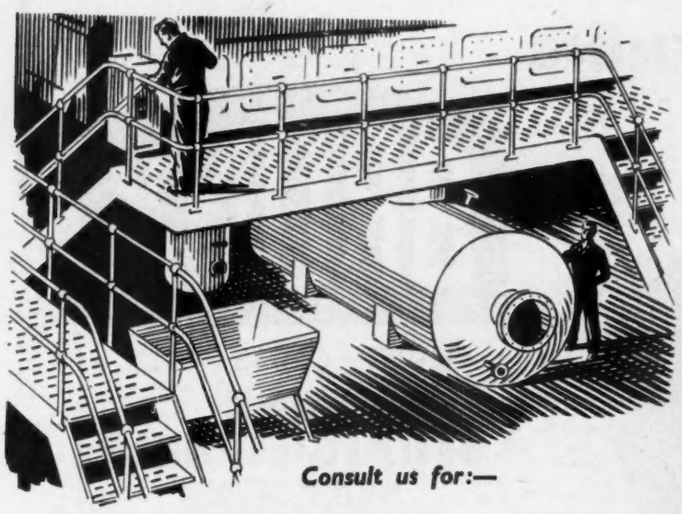

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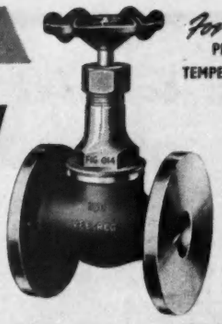

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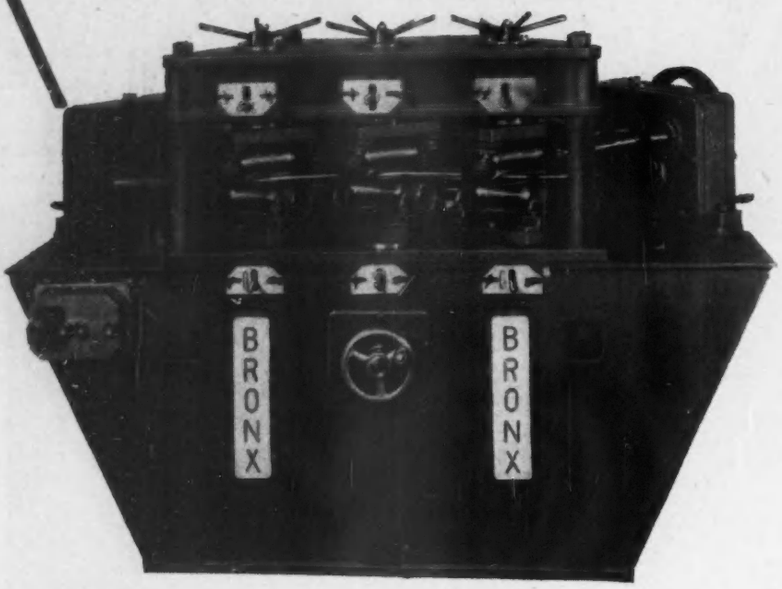


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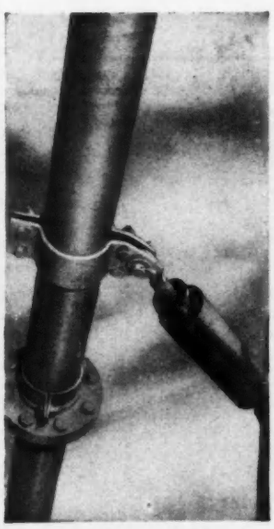

Shocks and vibration give rise to high stresses in pipework, with possible subsequent damage to piping and associated equipment. Pipework on board ship subjected to vibration or in land installations exposed to high winds, is particularly prone to these hazards.

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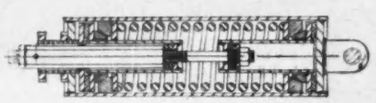
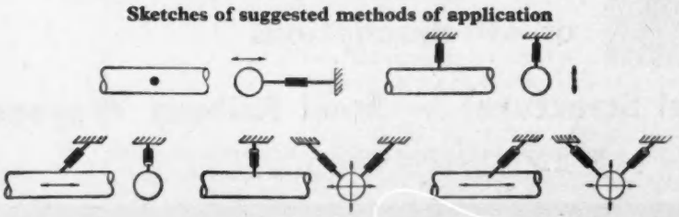


## Vokes Genspring Non-Resonant Sway Braces

**Sketches of suggested methods of application**



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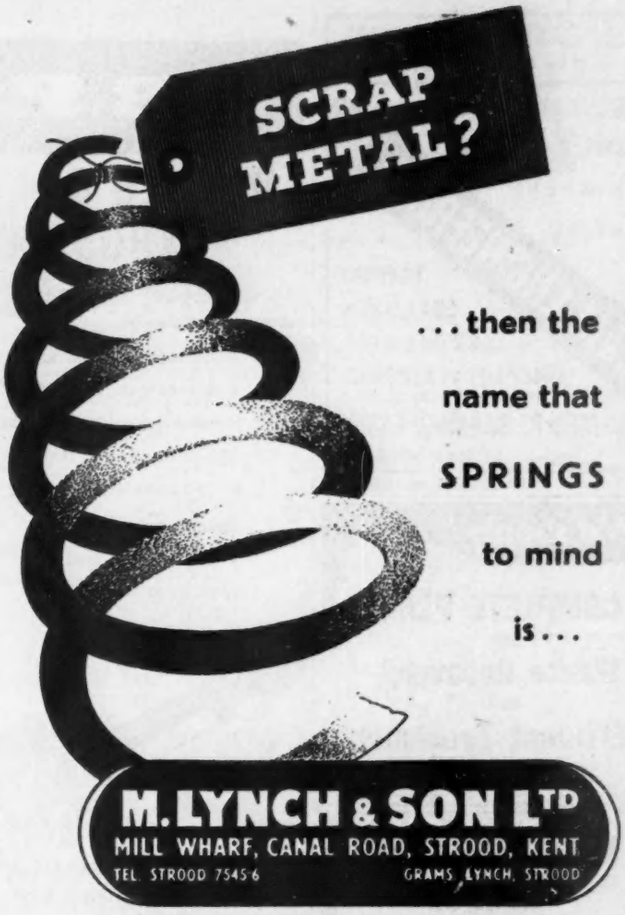
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MADE IN THE FOLLOWING SIZES : ½" or ¾", 1" or 1¼", 1½" or 2" and suitable for all PRESSURES UP TO 180 lbs. per sq. in.

CANNOT BECOME AIRLOCKED—WILL LIFT ITS DISCHARGE—CAN BE EXAMINED WHILE WORKING. THE MOST ECONOMICAL, EFFICIENT AND SAFEST TRAP ON THE MARKET. THE TRAP WITH THE FRICTIONLESS LOOSE DISC VALVE.

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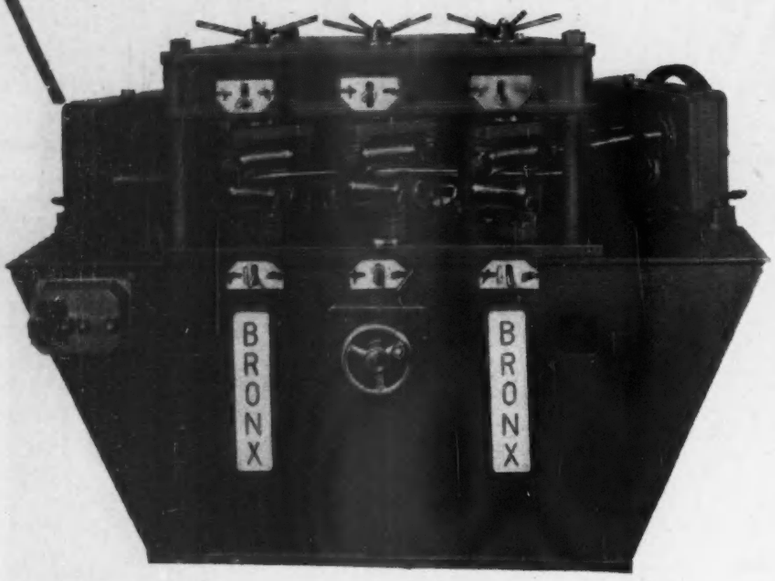


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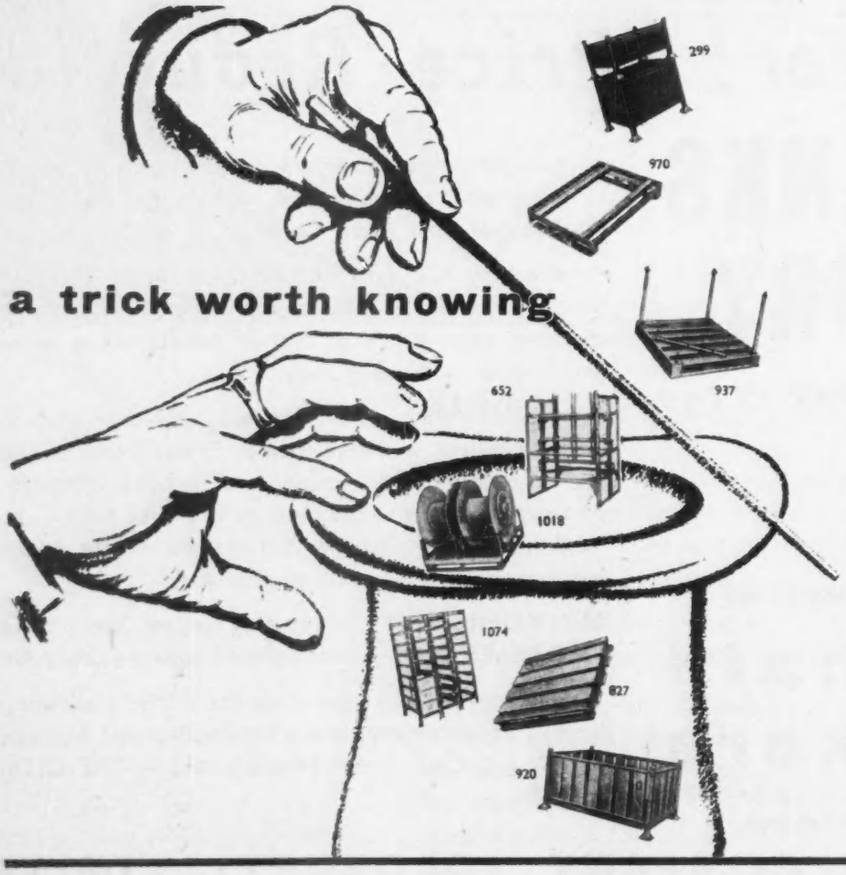


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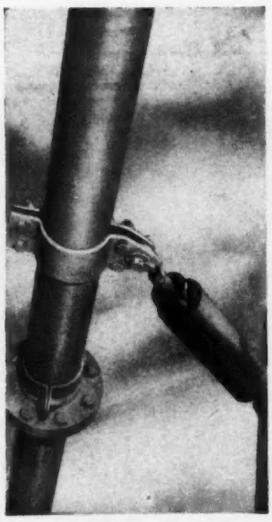
# "Bracing" weather for pipework



Shocks and vibration give rise to high stresses in pipework, with possible subsequent damage to piping and associated equipment. Pipework on board ship subjected to vibration or in land installations exposed to high winds, is particularly prone to these hazards.

Vokes Genspring Non-Resonant Sway Braces supply an efficient form of control on all such pipework. These Sway Braces have many unique features including an incorporated energy-absorbing device, adjustability of initial restoring force, laminated cushioning material to reduce operational noise, and travel stops to prevent compression of springs to solid height. The eight different spring sizes cover loads from 39 lb. to 1,500 lb., with maximum restraining force varying from 100-2,250 lb. due to spring action.

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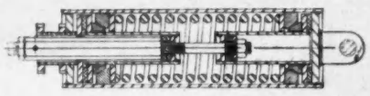
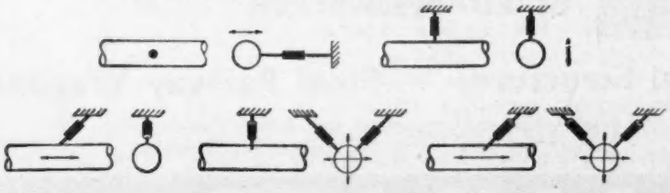


## Vokes Genspring Non-Resonant Sway Braces

**Sketches of suggested methods of application**



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MADE IN THE FOLLOWING SIZES : ½" or ¾", 1" or 1¼", 1½" or 2" and suitable for all PRESSURES UP TO 180 lbs. per sq. in.

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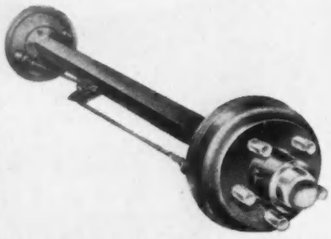

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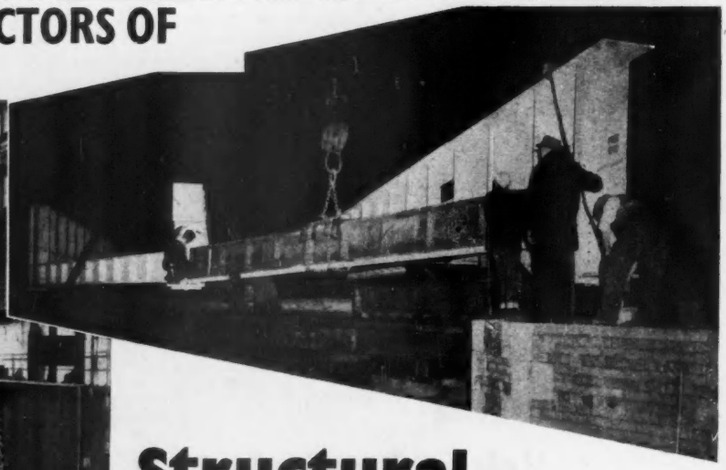

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*Electrical Aids in Industry* *Data Sheet* **No. 9**

# Lighting - 3

Data Sheet No. 7 dealt with some actual applications of factory lighting. Further applications are given here.

***Drawing Offices***

It is fair to say that in no part of a factory is good lighting more important than in the drawing office. The draughtsman's task is extremely exacting and unless the illumination is up to required standards, mistakes, loss of time and greater fatigue will result.

***The essential requirements are:***

High value of illumination
(*minimum of 30 foot-candles on the boards*)
Absence of shadows
Absence of reflection

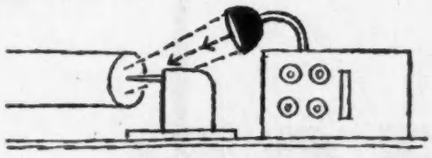
One of the major problems is the reflection of the light sources by shiny tracing paper, instruments, set-squares, etc., and particularly by the extra-hard pencil leads often used. Another problem is that caused by shadows ahead of T-squares and by the variety of angles at which drawing boards are set.

Fluorescent lighting is particularly suitable because of its comparative freedom from shadow, its natural colour and because it can be localised with respect to drawing boards to avoid reflections while at the same time giving enough light upward and sideways to satisfy the general lighting requirements of the office.

A lighting solution which has been successfully employed for tracing is to light from beneath and through the paper which is fixed on to a translucent panel, thus eliminating the problems of shadow and reflection.

***Machine Shops***

The problems of machine-shop lighting vary so widely that it is impossible to lay down rigid rules which are applicable to all types of machine. Much of the design of such lighting systems must therefore be a matter of individual application. Certain maxims, however, have proved in practice to be satisfactory in various trades.

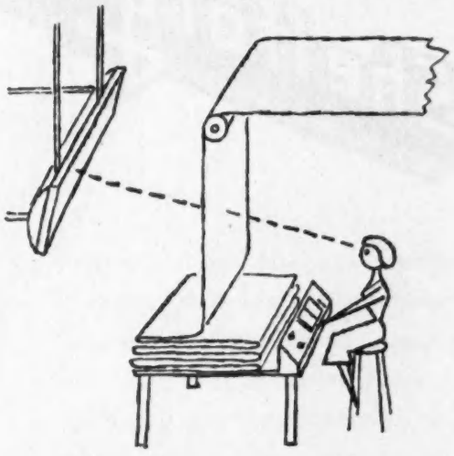


There is a strong case for the provision of local lighting on many machines to enable the direction of light to be varied to suit the work, or to boost the illumination for fine work.

In shops employing certain machine tools, particularly circular saws, the possibility of stroboscopic effects can be avoided by splitting lamps among the phases of a three-phase supply or by using twin lamp fittings with a split-phase circuit.

Where safety goggles are used, extra illumination should be provided to compensate for the reduced light reaching the eyes.

Silhouette inspection of fabrics or profiles can often be used to advantage by placing a light source behind the material to be inspected — on the lines of the back-lighting already referred to for tracing in the drawing offices.



In general, machine-shop lighting is essentially an empirical science, based largely on a combination of general and local lighting, which offers immense scope for ingenuity.

***Outside Lighting***

The outside precincts of a factory are often much neglected. No special rules can be suggested for lighting these areas, but speed, efficiency and safety are all dependent on adequate outside illumination during the hours of darkness.

***Conclusion***

Works Managers and Executives, while recognising the importance of their artificial lighting, cannot be expected to make a detailed study of the subject which has been only briefly dealt with in these data sheets; but they are interested in knowing whether their lighting is contributing to efficient production and whether they are getting full value for the expenditure on it.

This is where the expert can help.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2. Telephone: TEMple Bar 9434.

Excellent reference books on electricity and productivity (8/6 each or 9/- post free) are available—"Lighting in Industry" is an example.

E.D.A. also have available on free loan in the United Kingdom a series of films on the industrial uses of electricity, including one on industrial lighting. Ask for a catalogue.

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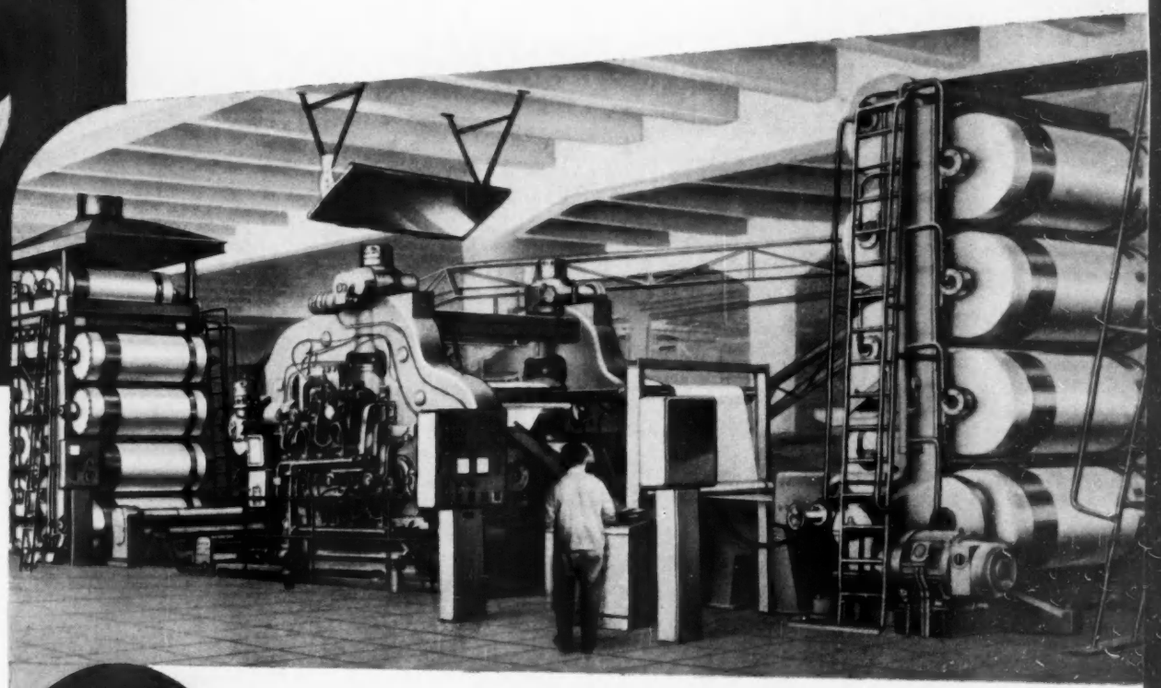

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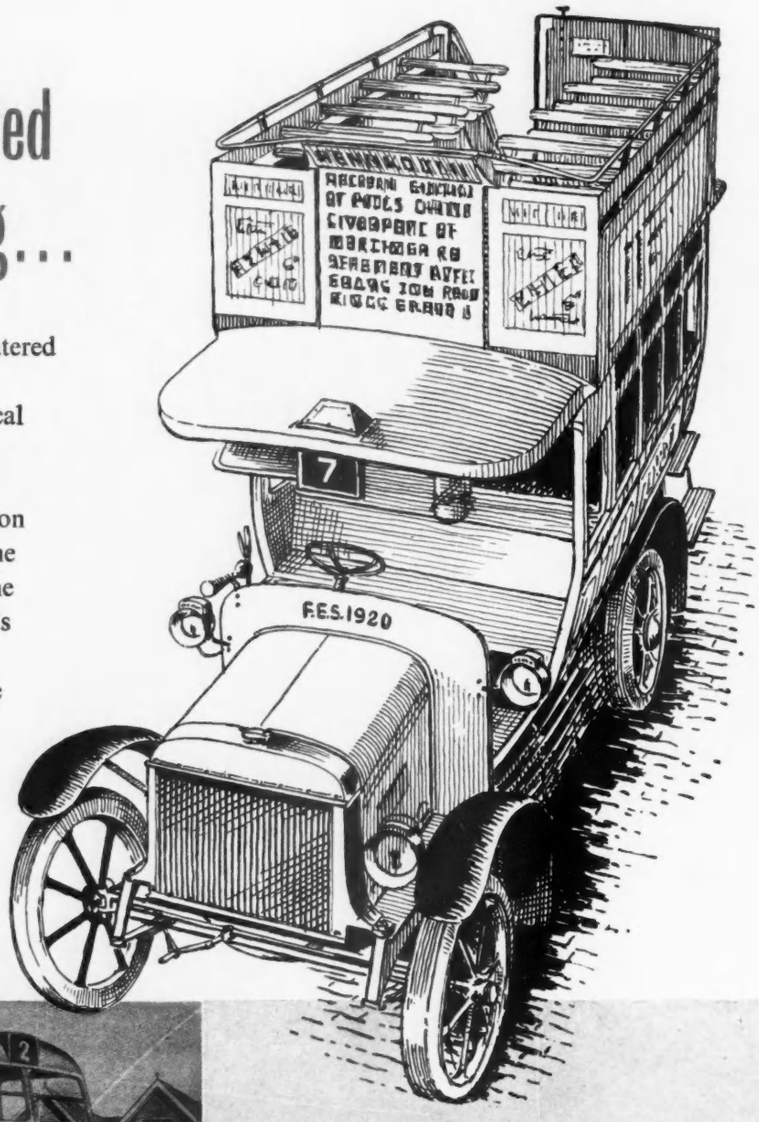

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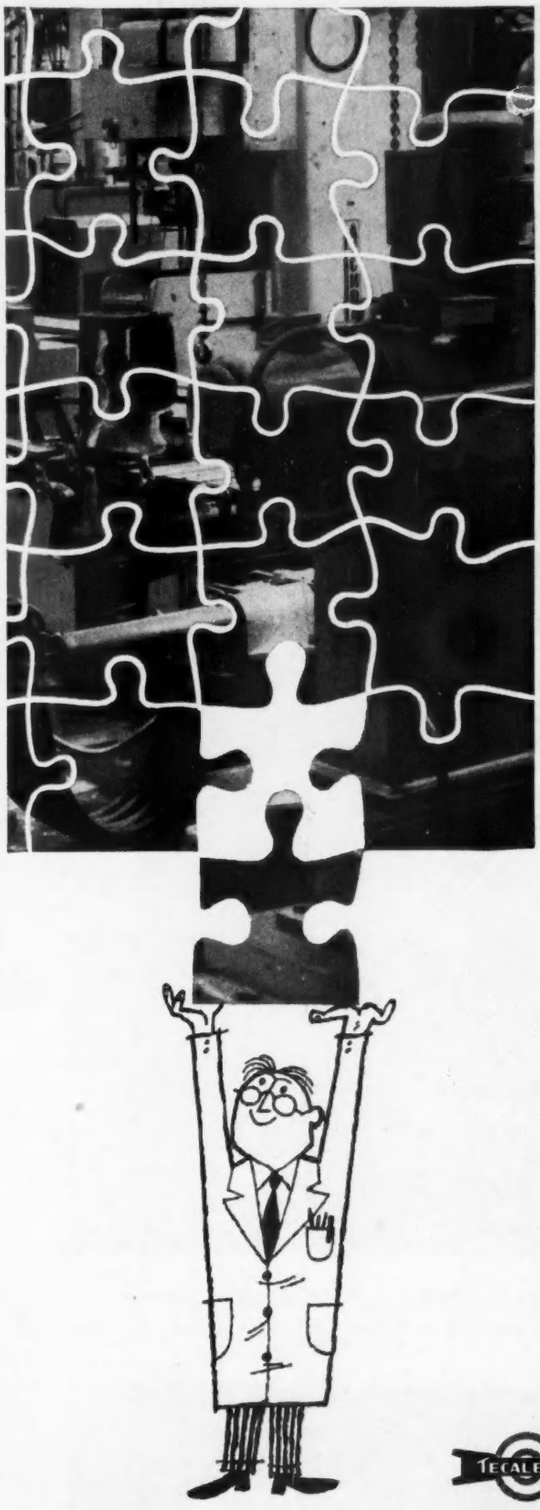

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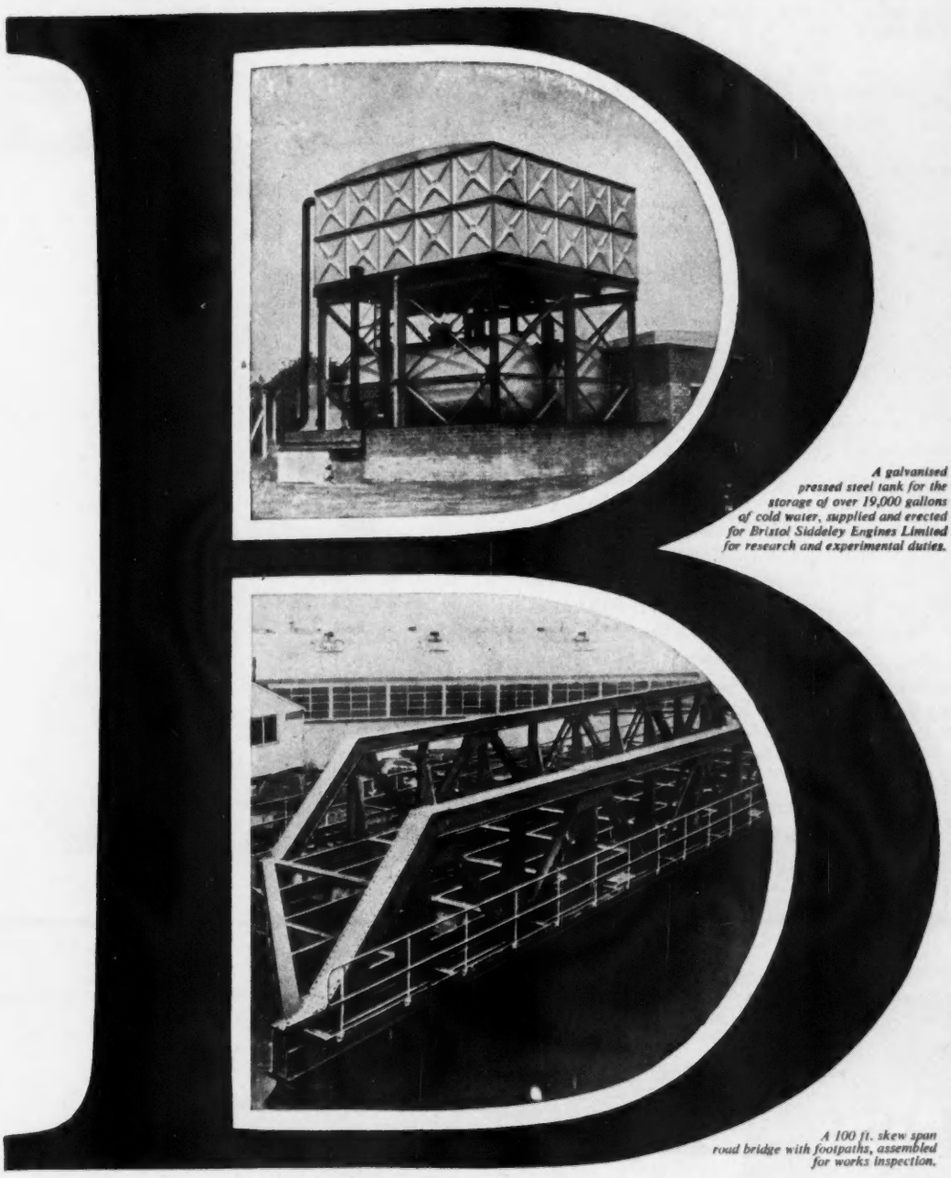

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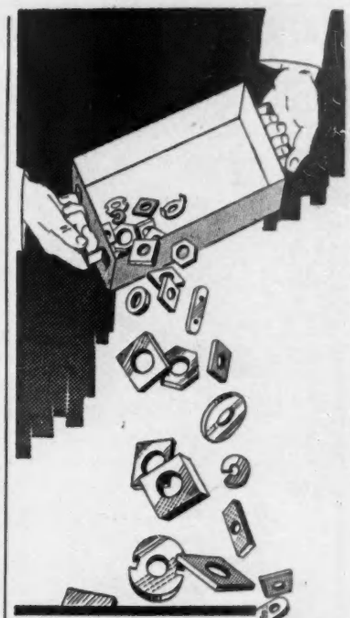

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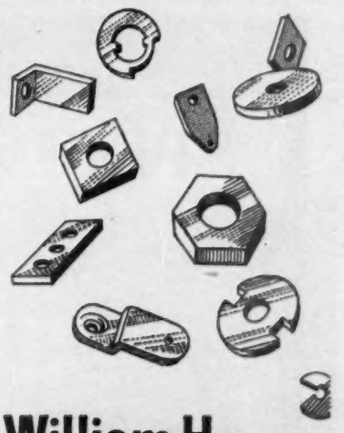

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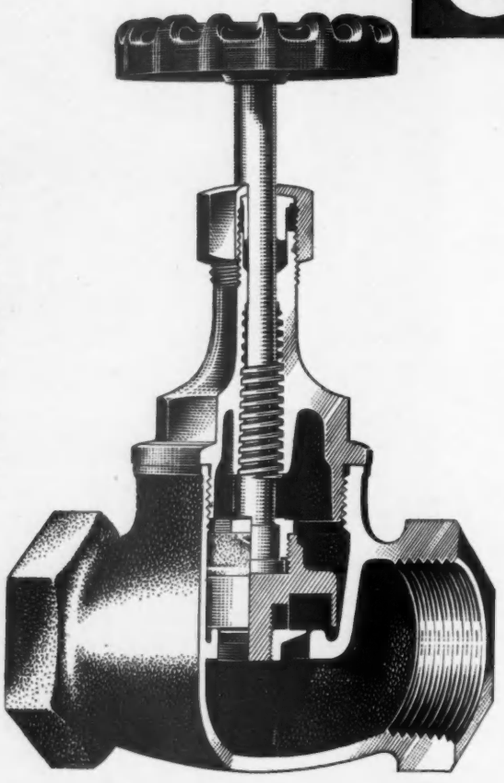
BULLETIN ON CRANE BRONZE GLOBE VALVES

...featuring the D5 with renewable composition disc. An important feature of the D5 is the composition disc which is easily removed for renewal. This valve is made in accordance with British Standard 2060 and is recommended for a wide range of services - steam and hot water lines as well as cold services such as water, oil, gas and air. It can be specially packed for petrol service and in all cases can be repacked under pressure. Screwed or Flanged valves available. (Screwed British Standard Taper Threads - or to American Standards. Flanged in accordance with British Standard Tables 'D' and 'E' - or to American Standards.)
Sizes: Screwed - ¼" to 2". Flanged - ½" to 2". Working Pressures: Screwed saturated steam up to 125 pounds. Cold services up to 200 pounds.



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CRANE LTD., 15-16 RED LION COURT, FLEET ST., LONDON, E.C.4 · Works: IPSWICH
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**GLOUCESTER**

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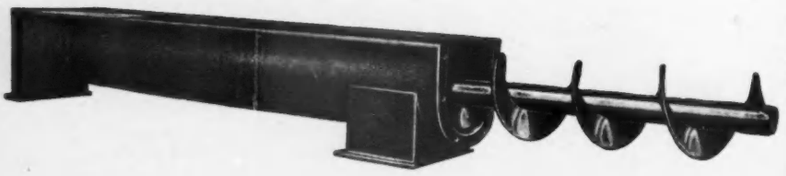

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EMINENTLY SUITED FOR CONVEYING BULK MATERIAL ALONG HORIZONTAL DISTANCES OR CAN BE USED AT ANGLES UP TO 30°

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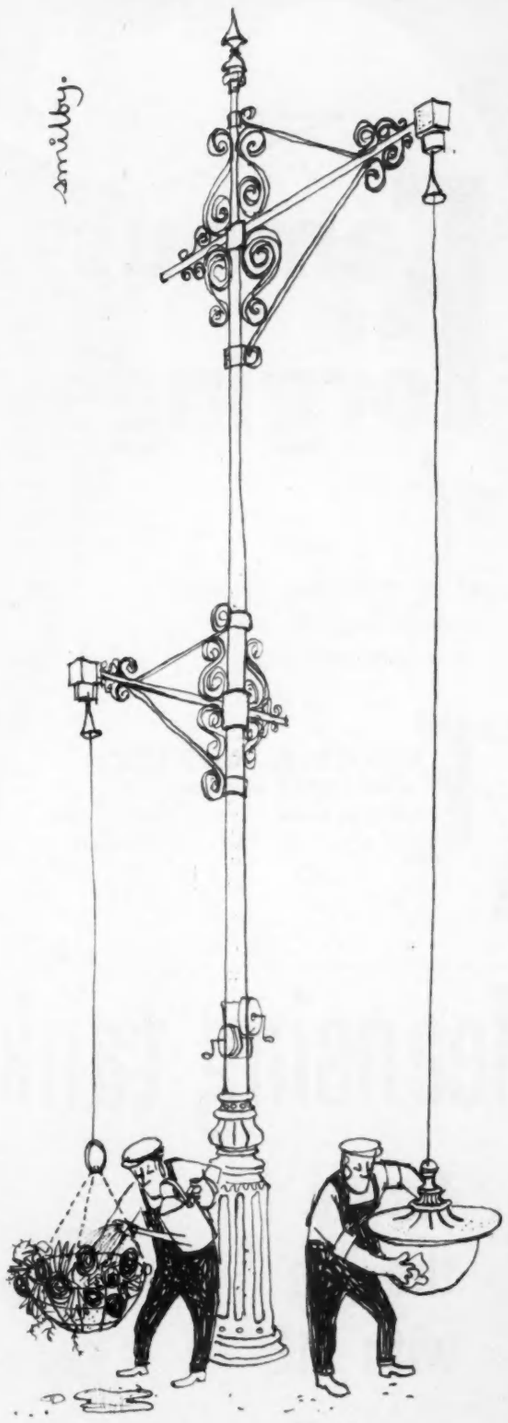


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*L. E. F. RAISING AND LOWERING GEAR*

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**LONDON ELECTRIC FIRM LIMITED**
Brighton Road, South Croydon, Surrey. *Telephone : Uplands 4871.*

*Drawing reproduced by arrangement with the "Tatler".*

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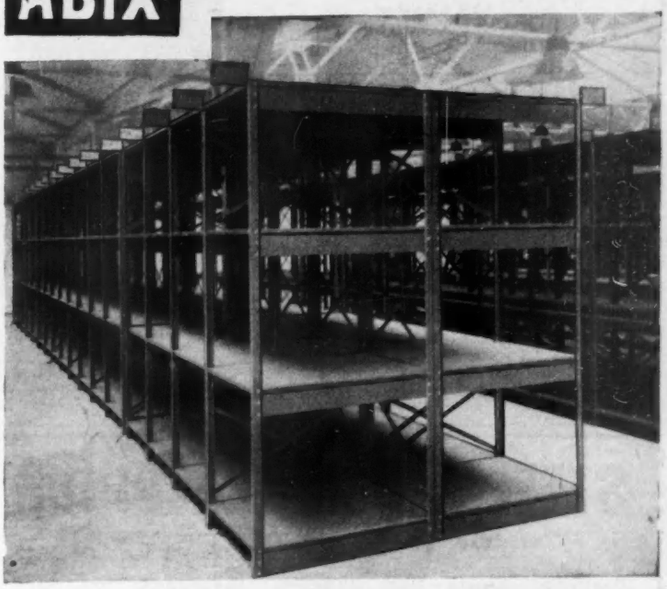
**ABIX** **ADJUSTABLE STEEL SHELVING**



The illustration shows a typical installation of ABIX Steel Shelving, supplied to a well-known Paint Manufacturer. Note the easy access to the shelving and the orderly appearance.
ABIX Steel Storage Equipment is supplied in a number of Standard components which can be used to make up an infinite variety of assemblies to suit your particular need. These components can be erected and dismantled by unskilled labour in a minimum of time.
They are Steel throughout. Stove Enamelled Olive Green. All fixing bolts are galvanized.

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ME Cleansing Tanks have been specially designed for cleansing and degreasing of engineering parts of every type. The tank illustrated is the type 2E electrically operated model.—**£89** with 3-phase motor, revolving spray extra.

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DIMENSIONS AS B.S. 2960
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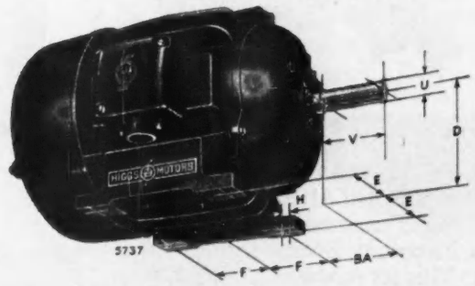


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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3000 | 1500 | 1000 | 750 | | | | | | | | | Width | Thickness |
| 1½ | 1 | ½ | — | D162 | 4 | 3½ | 2 | 2½ | ⅜ | ⅝ | 2½ | 3/16 | 3/16 |
| 2 | 1½ | ½ | ½ | D164 | 4 | 3½ | 2½ | 2½ | ⅜ | ⅝ | 2½ | 3/16 | 3/16 |
| 3 | 2 | 1 | ½ | D182 | 4½ | 3½ | 2½ | 2½ | 7/16 | 1⅛ | 3 | 5/16 | ¼ |
| 5 | 3 | 2&1½ | 1 | D184 | 4½ | 3½ | 2½ | 2½ | 7/16 | 1⅛ | 3 | 5/16 | ¼ |
| 7½ | 5 | 3 | 2&1½ | D213 | 5½ | 4½ | 2½ | 3½ | 7/16 | 1⅛ | 3⅜ | ¼ | ¼ |
| 10 | 7½ | 5 | 3 | D215 | 5½ | 4½ | 3½ | 3½ | 7/16 | 1⅛ | 3⅜ | ¼ | ¼ |
| 15 | 10 | 7½ | 5 | D254 | 6½ | 5 | 4½ | 4½ | 9/16 | 1⅛ | 4½ | 7/16 | 5/16 |
| 20 | 15 | 10 | 7½ | D256 | 6½ | 5 | 5 | 4½ | 9/16 | 1⅛ | 4½ | 7/16 | 5/16 |
| 25 | 20 | — | 10 | D284 | 7 | 5½ | 4½ | 4½ | 9/16 | 1½ | 5⅛ | ⅜ | 5/16 |
| 30 | 25 | 15 | — | D286 | 7 | 5½ | 5½ | 4½ | 9/16 | 1½ | 5⅛ | ⅜ | 5/16 |
| — | 30 | 20 | 15 | D324 | 8 | 6½ | 5½ | 5½ | 11/16 | 2⅛ | 6⅝ | ⅜ | 7/16 |
| — | 40 | 25 | 20 | D326 | 8 | 6½ | 6 | 5½ | 11/16 | 2⅛ | 6⅝ | ⅜ | 7/16 |

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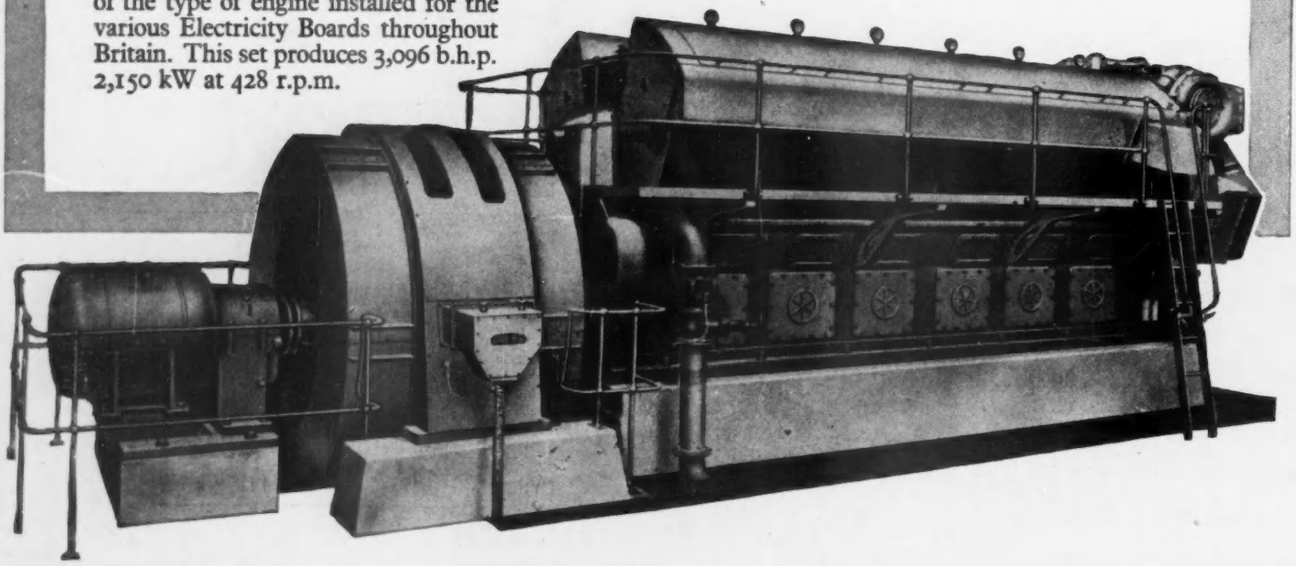
A Mirrlees KVSS12 Diesel Engine, coupled to a Brush Alternator, typical of the type of engine installed for the various Electricity Boards throughout Britain. This set produces 3,096 b.h.p. 2,150 kW at 428 r.p.m.



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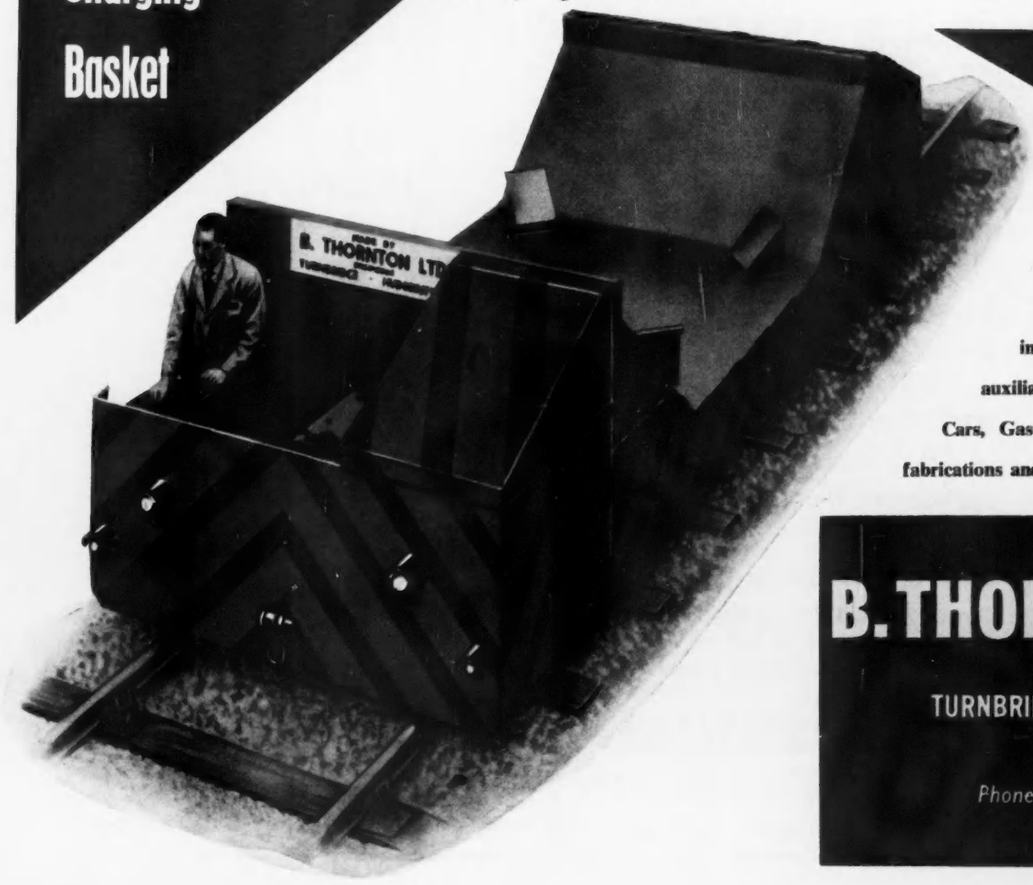


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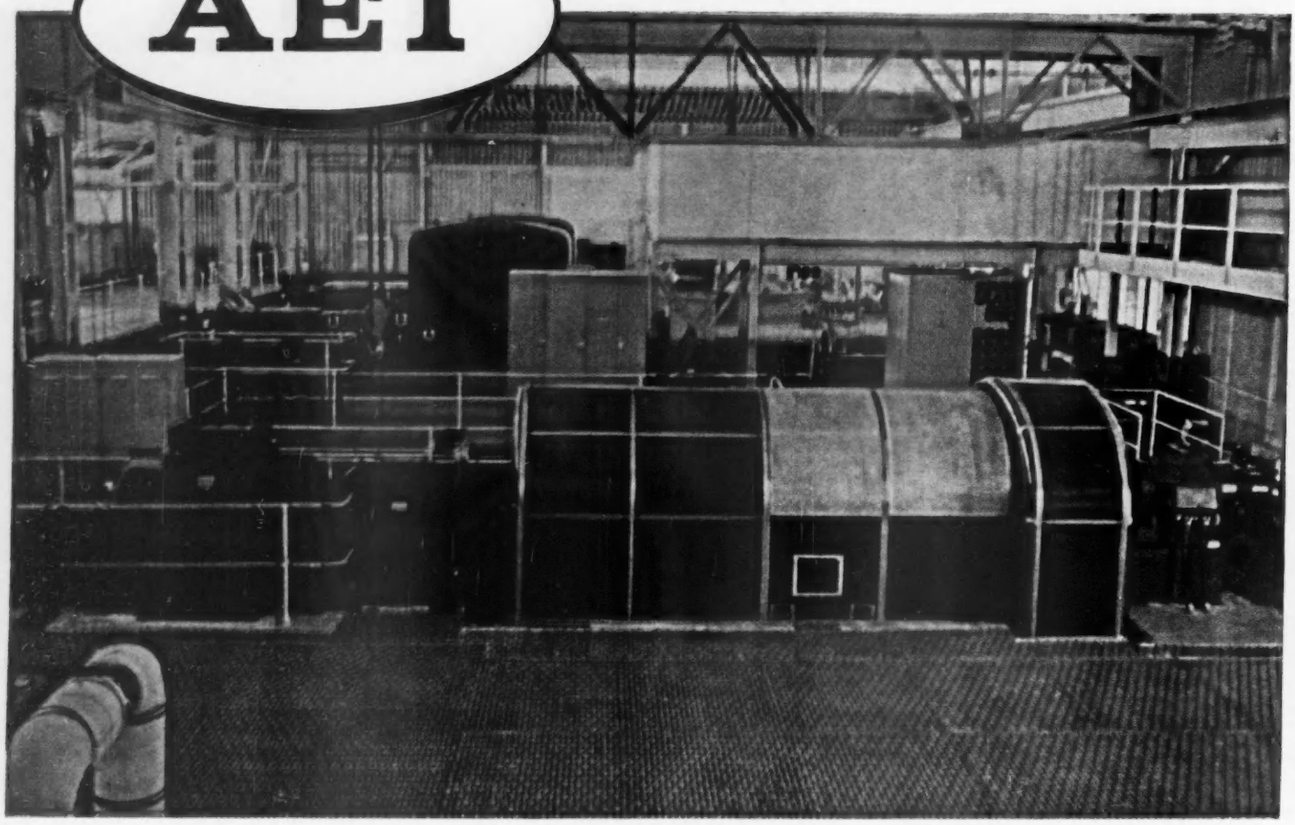

# 1750 kW GAS TURBINE-GENERATOR

## Over 19,000 Hours Base Load Service in VENEZUELA

The 1750 kW gas turbine-generator, on base load service in a Shell oilfield near Maracaibo, Venezuela, has completed more than 19,000 hours running on natural gas from the oilfield.

It is a typical example of the Series L axial-flow industrial gas turbines manufactured by AEI Turbine-generator Division for electrical generation and mechanical-drive applications, with ratings between 1750 kW and 22,000 kW.

Units of 4000 kW and 4500 kW are being supplied to oilfields in Iran and British North Borneo, and a similar machine is being built under licence, in Italy.

*For further details write to AEI Turbine Generator Division, Trafford Park, Manchester 17, or write to your local AEI office.*

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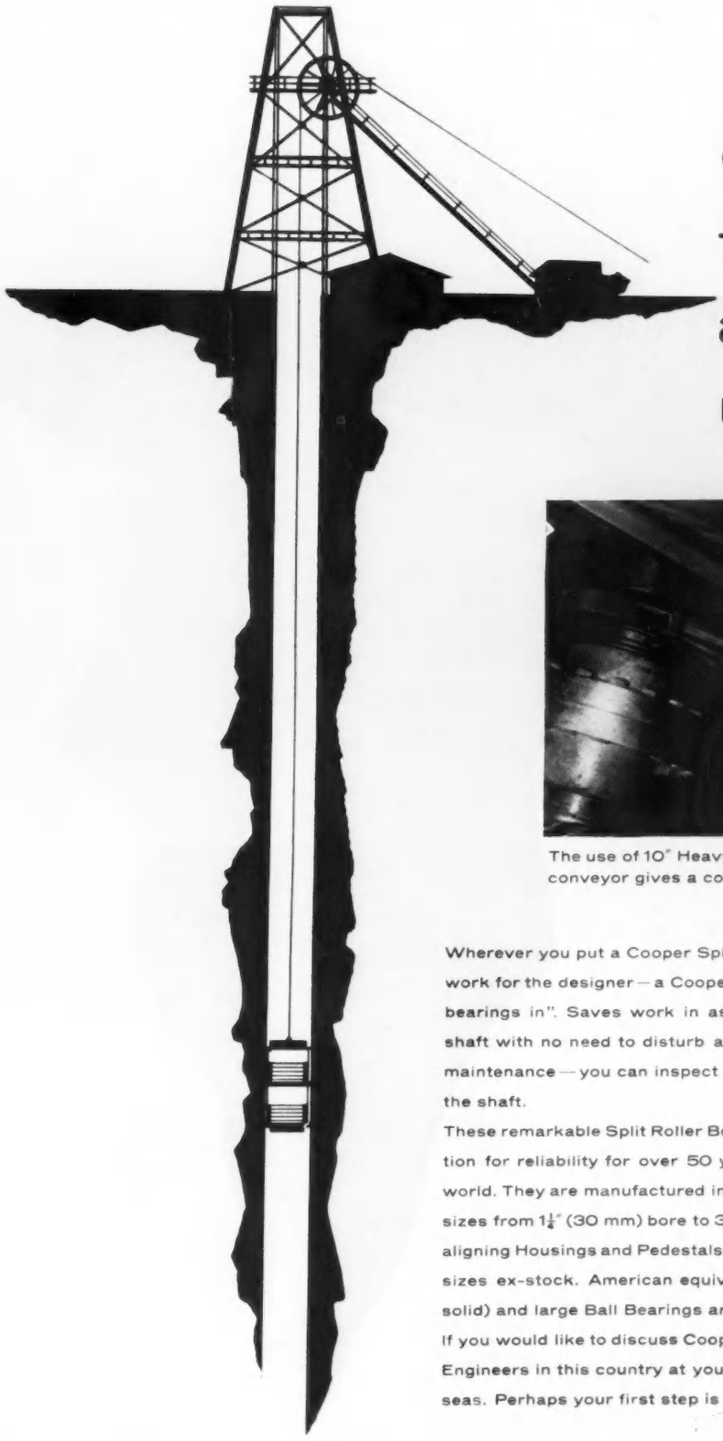
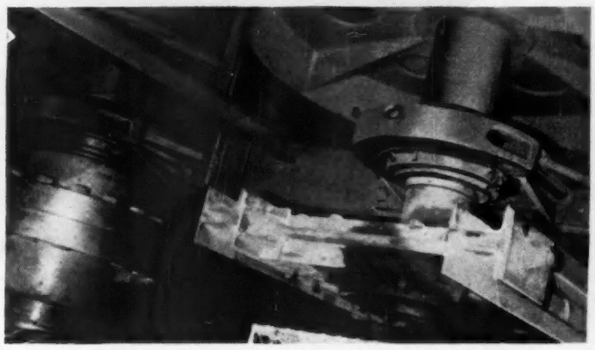


# Coopers on the surface... and Coopers underground...



The use of 10" Heavy Series Cooper Bearings on this heavy duty conveyor gives a compact layout—with excellent accessibility.

Wherever you put a Cooper Split Roller Bearing to work, it *saves* work. Saves work for the designer—a Cooper cuts out all the worry about "how to get the bearings in". Saves work in assembly—a Cooper is simply *positioned* on its shaft with no need to disturb adjacent gears, couplings etc. Saves work in maintenance—you can inspect the actual rolling surfaces without disturbing the shaft.

These remarkable Split Roller Bearings have been earning an enviable reputation for reliability for over 50 years, in thousands of plants throughout the world. They are manufactured in 3 series, Medium, Heavy and Extra Heavy in sizes from $1\frac{1}{4}$" (30 mm) bore to 30" (750 mm) bore, complete with sturdy self-aligning Housings and Pedestals. Prices? Competitive. Delivery? Rapid—many sizes ex-stock. American equivalents, large Roller Bearings (both split and solid) and large Ball Bearings are also manufactured to your requirements.

If you would like to discuss Cooper Roller Bearings there is a team of District Engineers in this country at your service—and agents in 54 countries overseas. Perhaps your first step is to send for our illustrated catalogue.

**COOPER** ROLLER BEARINGS

split right down to the shaft

REGISTERED TRADE MARK

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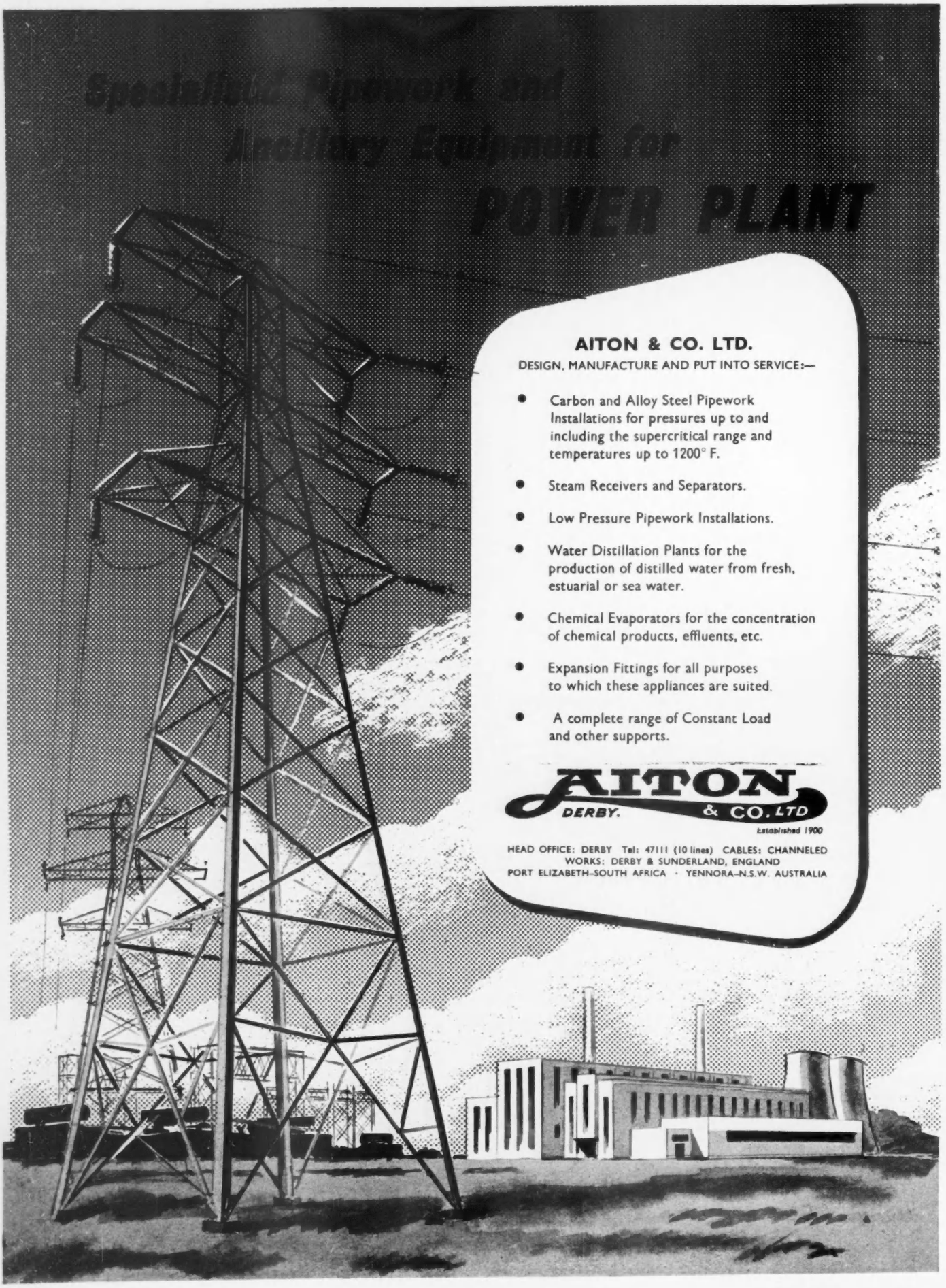
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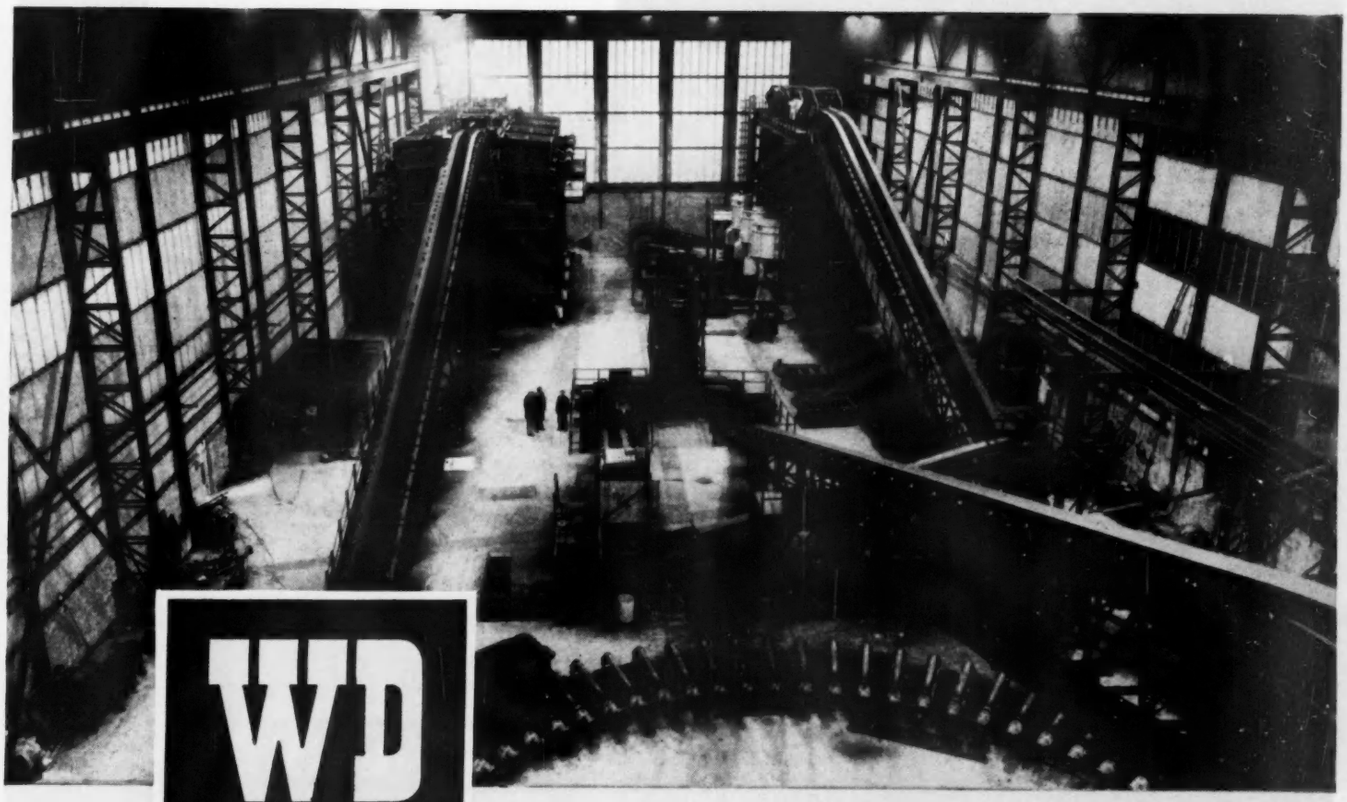
# A bath a minute!

*Westwood Dawes idlers are available with either grease packed self-lubricating bearings or with external grease nipples and one side lubrication pipes.*

3 Roller sets can have 4", 5" or 6" diameter rolls.
5 Roller sets can have 5" or 6" diameter rolls.

*A full range of tubular return idlers, rubber disc returns, impact idlers, steel pulleys and tension gear, etc., is also available.*

***Send for our Catalogue now!***



**WD**

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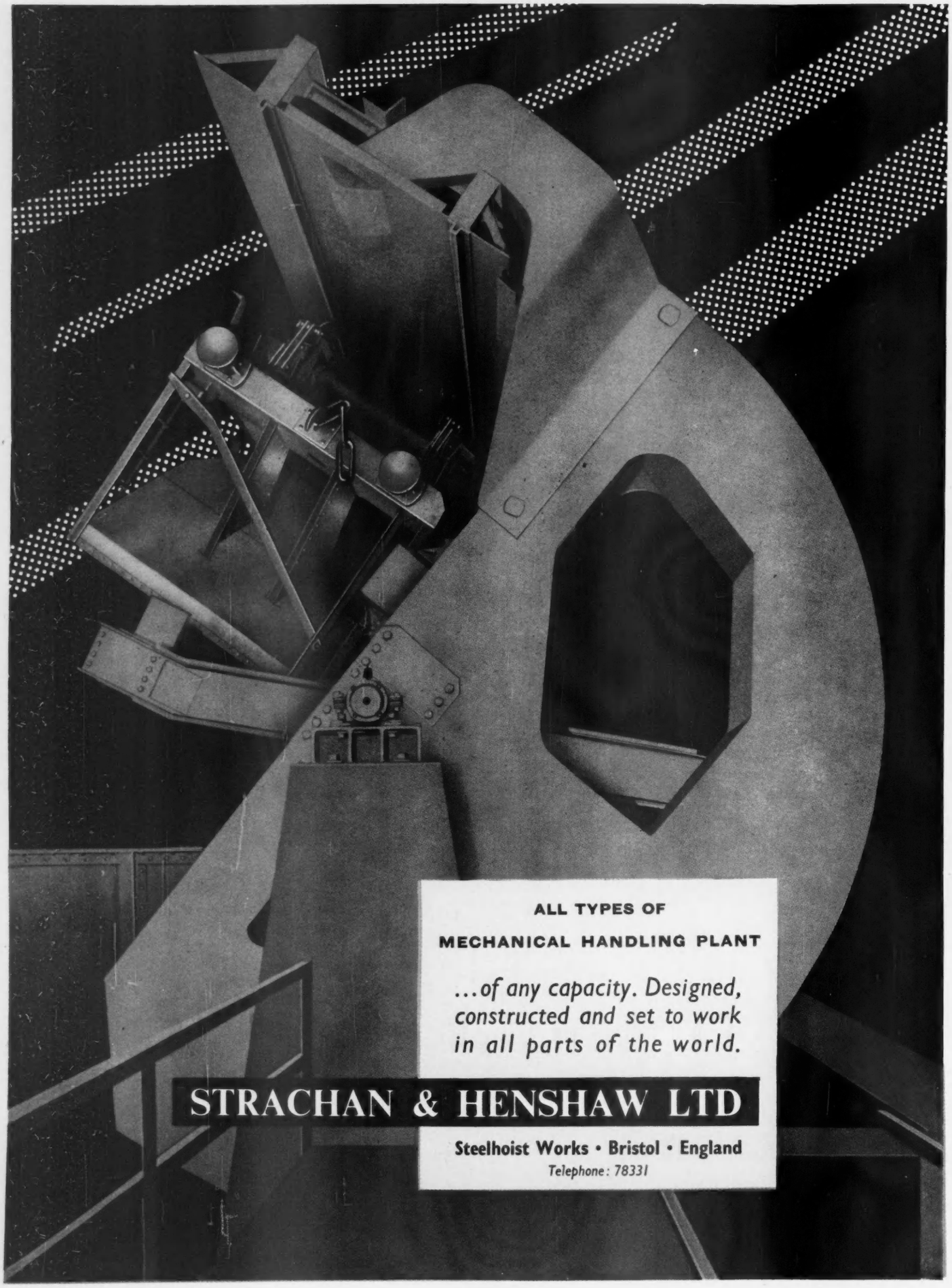
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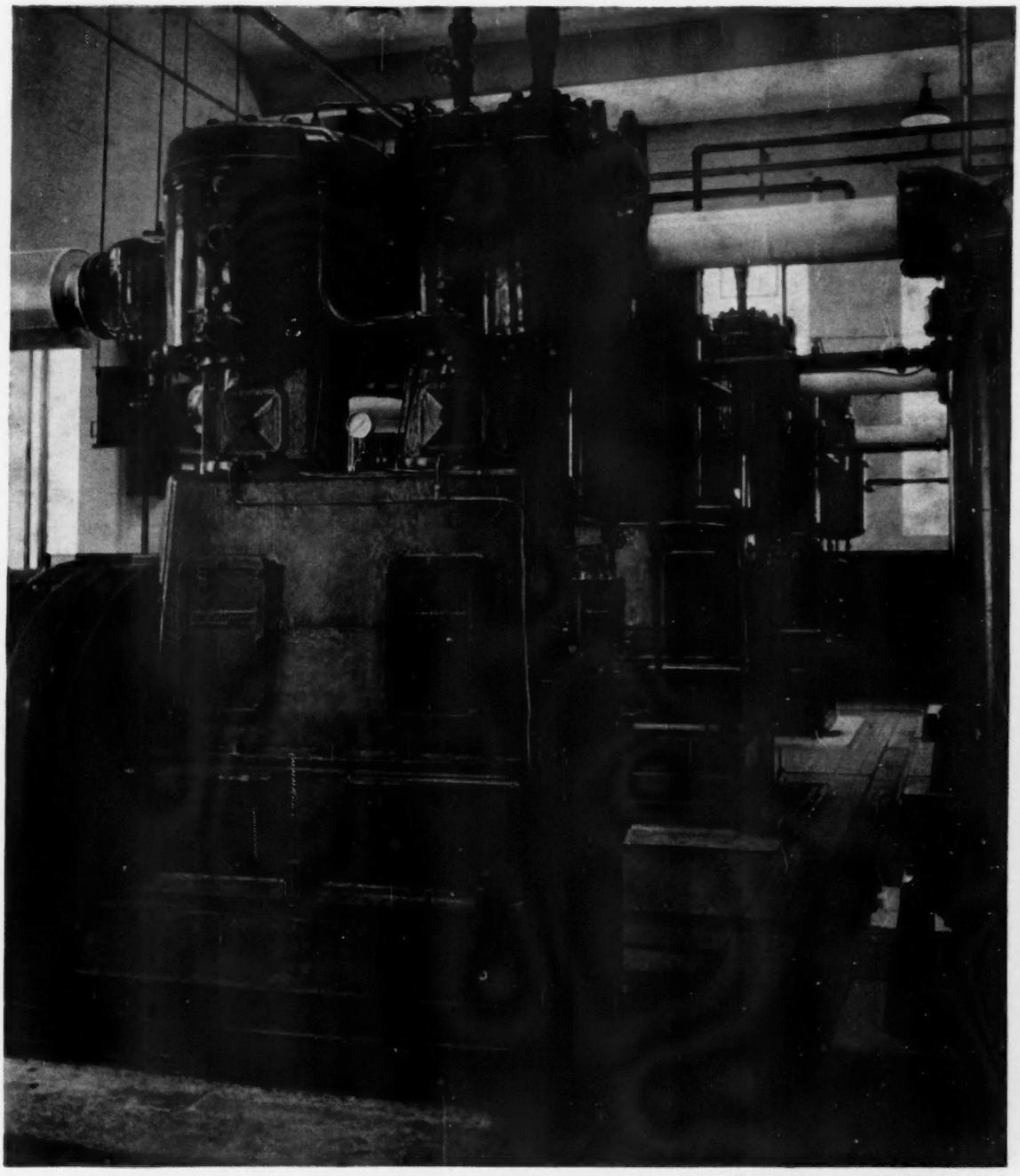

*Photograph by courtesy of Raleigh Industries Ltd.*

# RALEIGH INDUSTRIES CHOOSE "BROOMWADE"

The three type TS2X models illustrated, each delivering 1000 cu. ft. of free air per minute, are installed in one of the factories of RALEIGH INDUSTRIES LTD., where they supply air for a wide variety of duties.

Why do so many important organisations choose " BROOMWADE "?

For proven ECONOMY, EFFICIENCY, RELIABILITY and LONG LIFE.

In the wide " BROOMWADE " range, you will find compressors with outputs from 2–2200 c.f.m., including types delivering oil-free air.

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**BROOM & WADE LTD., P.O. BOX NO. 7, HIGH WYCOMBE, ENGLAND** · *Telephone : High Wycombe 1630 (10 lines)* · *Telegrams : " Broom ", High Wycombe. (Telex)*

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For hammered or hydraulically pressed forgings from a few pounds to Twenty Five tons—it pays to leave it to LANGLEY.

Ample heat treatment and machining capacity available.

*Natural colour photograph showing 28 ton ingot being forged into sow blocks from E. N. 16A steel.*

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# HEAVY DUTY LEVEL LUFFING GRABBING CRANES FOR RAPID DISCHARGE OF BULK CARGOES

**Clyde Cranes on the new coal transfer jetty of**

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Natural colour photograph showing 24 ton ingot being forged into a block 6 ft. 6 in. long by 3 ft. 6 in. square in 4 steps

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# *Leave it to* LANGLEY

*Natural colour photograph showing 28 ton ingot being forged into tow blocks from E. N. 16A steel.*

LANGLEY steel forgings are used by Harwell, Calder Hall, British Railways, Durgapur Steel Works, Iranian Oil Services and many other world famous companies.

For hammered or hydraulically pressed forgings from a few pounds to Twenty Five tons—it pays to leave it to LANGLEY.

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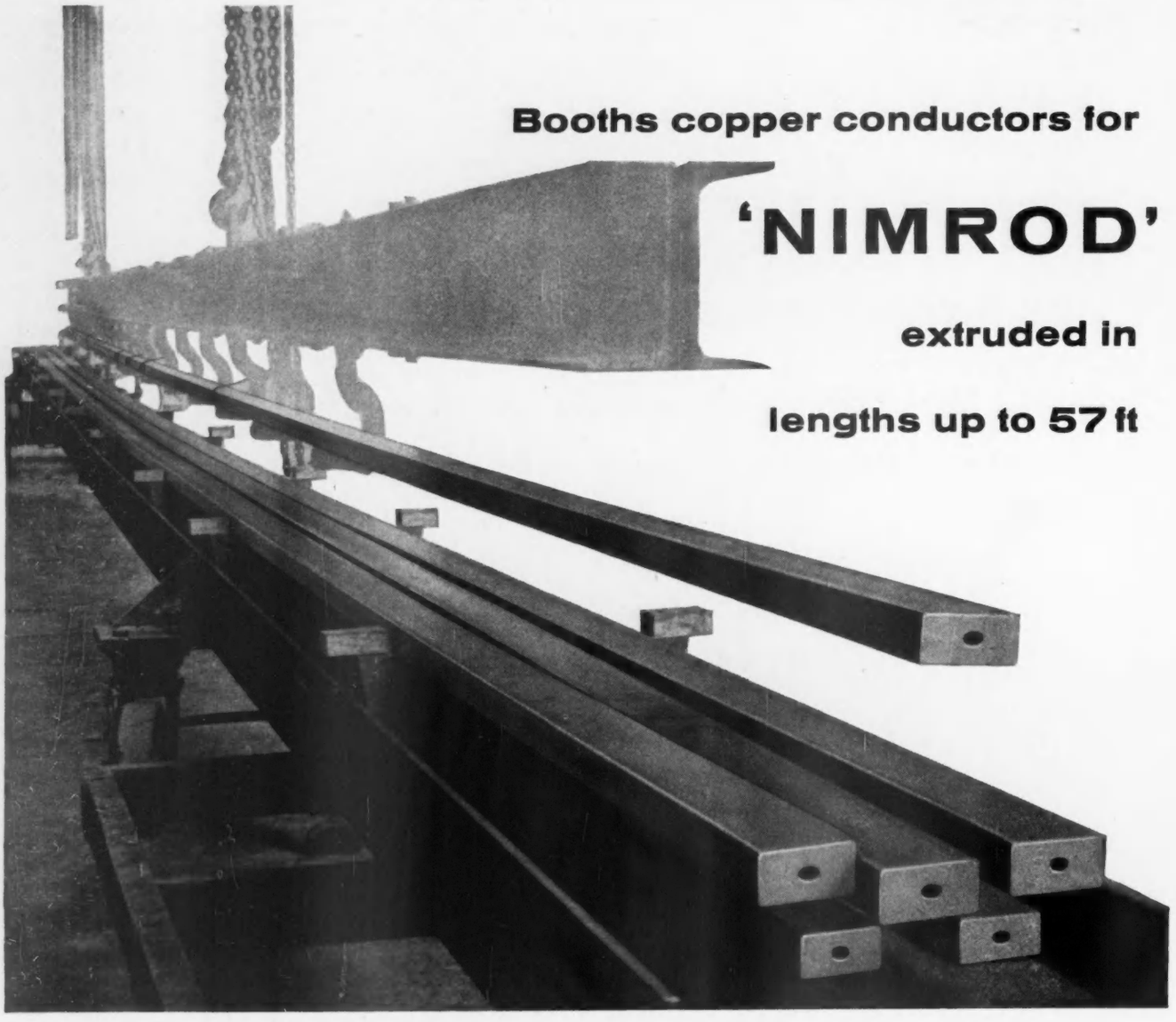
# Booths copper conductors for 'NIMROD' extruded in lengths up to 57 ft



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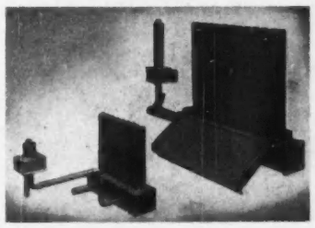

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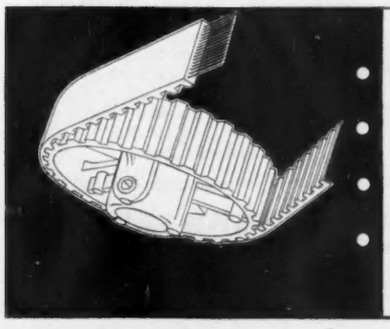

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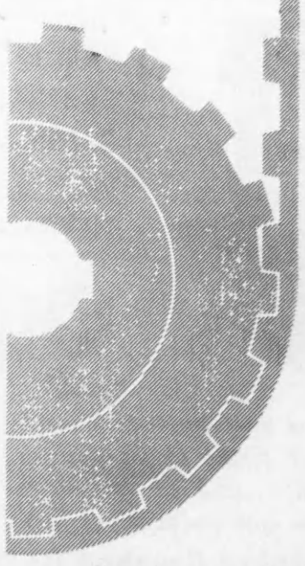

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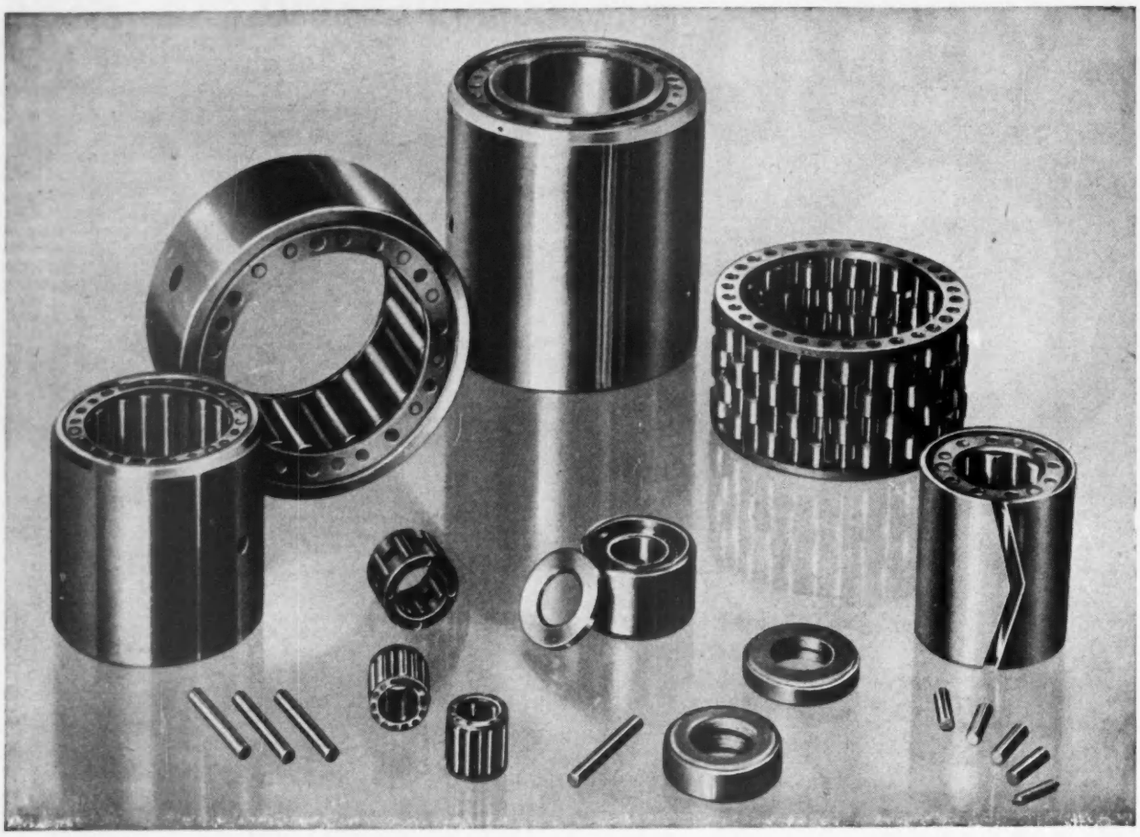

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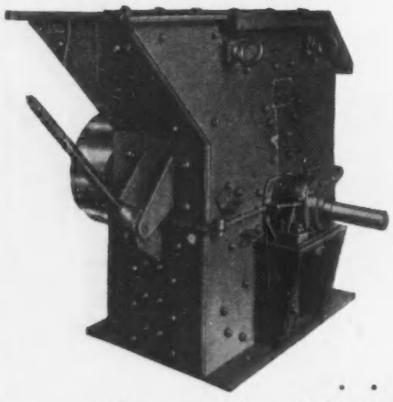

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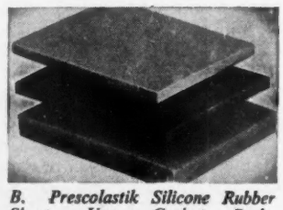

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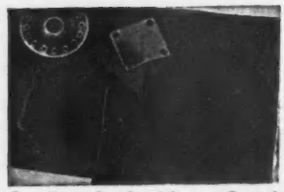

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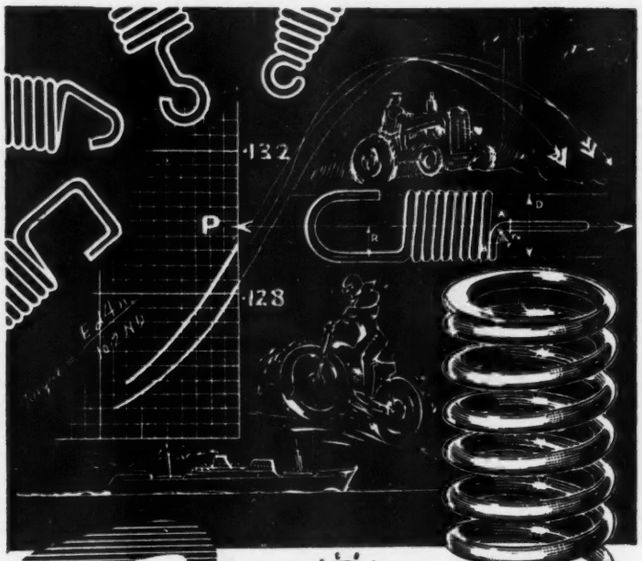


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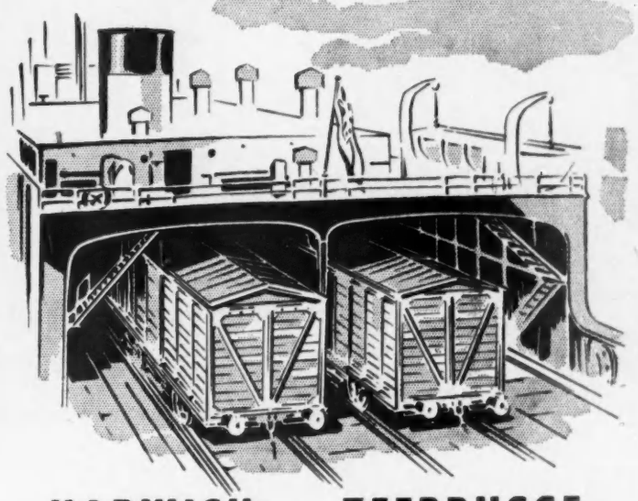

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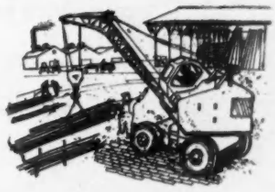

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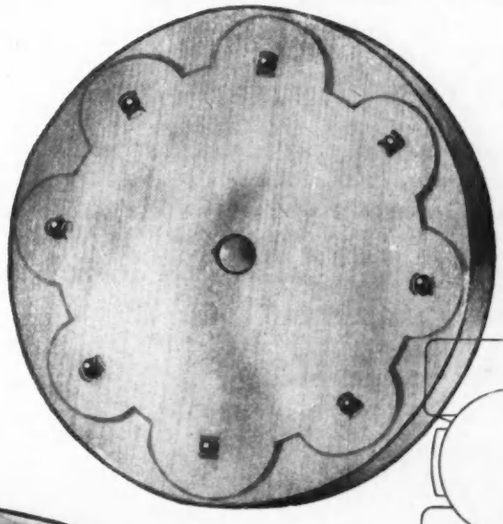
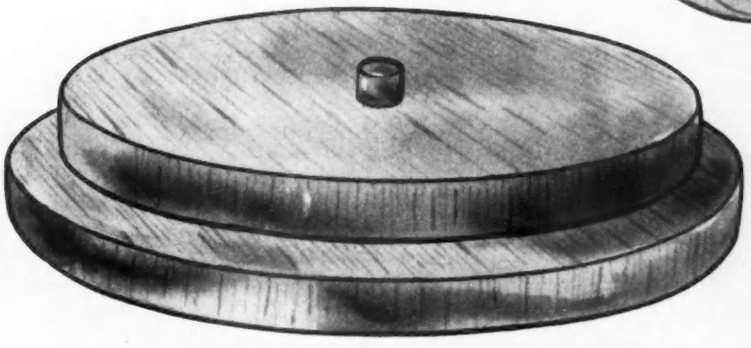
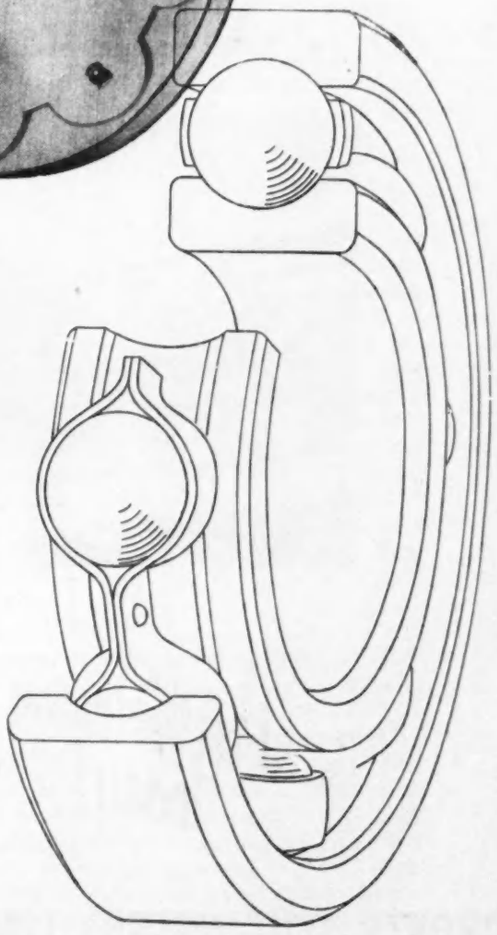


*Artist's drawing of Roman ball bearing found in Lake Nemi*





*Cut-away drawing of modern (S.K.F.) ball race*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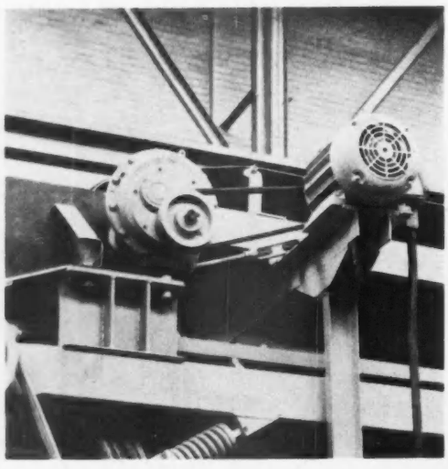

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# THE ENGINEER

No. 5427 JANUARY 29, 1960 VOL. 209

## CLEANER RIVERS SOONER

A lot of what seems to us very good sense is expressed in the final report published last Tuesday of the Trade Effluents Sub-Committee of the Central Advisory Water Committee. Especially do we applaud the committee's very obvious desire that, so far as it is practicable, industrial people shall be led to co-operate with, rather than oppose, the River Boards. Furthermore, there recurs more than once in the report an expressed desire to remove any reason for River Boards to indulge in any kind of " witch-hunting " for establishments attempting to evade their responsibilities. It is, of course, recognised that Boards must have powers to take legal or other action in certain circumstances. But much more stress is laid in the report on the devisal of measures which will make it more advantageous for any firm putting an effluent into a river or stream to give the River Board full particulars about it than to attempt concealment. The encouragement of co-operation is a key-note in the report.

There are a number of minor recommendations in the report, amongst them one that there should be no alteration of the common law relating to rivers, to which there is a minority " reservation " by two members of the sub-committee. Two major recommendations relate to the powers of River Boards in relation to discharges of polluting matter which were in existence before 1951 when the Rivers (Prevention of Pollution) Act was passed; and to the discharge of effluents to sewers respectively. Under the 1951 Act the consent of a River Board is required before any new effluent may be poured into a stream or river, but the Boards have no such powers in relation to effluents being discharged before 1951 and continuing to be discharged now. Also under the 1951 Act the Boards are empowered to make bye-laws fixing standards for acceptable effluents. No such bye-laws have so far been made ; nor apparently have Boards felt any compelling urge to make them. After reviewing this situation the committee reaches the forthright but, in our view, justifiable conclusion that " any such bye-laws, unless revised frequently, would either bear unnecessarily harshly on those who make small discharges or be disastrous to the river." What River Boards have in fact done to control new effluents has been to lay down for each individual effluent standards of quality related to the quantity discharged. It has proved an effective method of control. The committee now suggests that the Boards shall be given similar powers in relation to pre-1951 effluents. To quote from the committee's recommendations, " Within a period of one year from the passing of any new legislation all dischargers should have to apply to River Boards for consent to continue their discharges." There would be provision for appeal to the Minister. It is sensibly envisaged that " it will not always be practicable for the first consents for pre-1951 discharges to be in such terms as to produce the ultimate possible improvement " so that provision will have to be made to review consent conditions from time to time. The compliance by any polluter with the new rule would confer upon it protection from prosecution until such time as the Board laid down conditions for its discharge ; and no time limit would be laid down for the Board to settle such conditions. The idea is that Boards would first lay down individual conditions to control those discharges which they knew to be particularly serious in their effects on the river, and only later tackle others. On the matter of discharges to sewers the committee found that there is some dissatisfaction with the existing situation under the Public Health (Drainage of Trade Premises) Act of 1937. This Act allows certain premises which discharged effluents to sewers in the year ended March 3, 1937, to continue doing so without obtaining the consent of the local authority and upon payment of sums in accordance with the terms of any agreement which was in force at the end of that year. The committee feels that " it is unreasonable to expect the local authorities to continue to deal with these effluents on financial arrangements made in 1937 or earlier and that they should be authorised to make reasonable charges . . . and to vary the charges . . . having regard to the cost of . . . treatment." Some other minor changes are also suggested.

But perhaps the most encouraging thing written into the report is a view expressed in an early paragraph. It reads, " in the course of our examination of witnesses we have been struck by the evidence of a general desire amongst those discharging effluents to rivers to co-operate in securing their improvement. There is developing a public sensibility to the poor state of many of our rivers, an increasing awareness of the amenity, recreational and health value of clean rivers and a general will to secure within the bounds of what is practicable the greatest improvement in the shortest possible time . . . We believe the time is ripe for a great drive forward by all concerned towards the goal of clean rivers." Very many engineers will, we think, heartily agree.

## APPEAL TO PRICE

Early in December, the Chancellor of the Exchequer made an appeal to industry to reduce prices or, at least, to prevent them rising. His reason for doing so was clear enough. It is often argued that inflation could be avoided if wage increases were granted only when matched by simultaneous improvements in productivity in the industry concerned. That argument is fallacious because productivity does not increase at the same rate in all industries. Yet a wage rise in one industry, where it may be justified, is likely to trigger off similar rises in other industries, where it may not. Nor is it possible nowadays, even if it ever was, to allow widely different wage rates to rule within industries requiring men of

similar degrees of skill. Thus, unless, indeed, there can be a national wages policy, the linking of increases of wage rates to improvements in productivity cannot be expected to prove fully effective in preventing inflation. The alternative is to see that improvements in productivity are reflected in price reductions. Since a price reduction, even of capital equipment, should sooner or later be reflected in reduced retail prices of consumer goods the nation as a whole benefits from an improvement in the efficiency of any single industry or individual firm. There is no inflationary follow-up.

At first sight, therefore, it seems a very reasonable request which the Chancellor is making to industry. But, unfortunately, any discussion of prices raises a number of questions to which economists have as yet provided no clear answers. A century or so ago economists supposed that prices were very largely settled by laws of supply and demand. But nowadays prices do not necessarily rise or fall according as to whether demand exceeds or falls short of supply. Instead firms appear to attempt to calculate their costs more closely than they used and to base their prices on those costs rather than on the demand for the goods. But there is a rub. For what are the true costs of producing anything ? For example, how much should be allowed for research ? Unless one has some conception of the likely return it is very difficult to calculate how much research is worth, not to speak of deciding how much of that cost to assign to any particular article produced. Again, how much profit should be ploughed back ? There are not wanting people who are critical of any substantial degree of ploughing back. They point out that when profits are ploughed back and a business is extended the buyers of the product finance the extension but it is the shareholders (not the buyers) who benefit by the greater capital value of their shares and the higher rates of interest paid upon them. Such critics maintain that rather than plough back profits, such firms ought to lower prices for the benefit of buyers and make new issues of shares to finance extensions. The argument is even applied to nationalised industries such as electricity supply. Is it sound ? Whether a firm will reduce prices in certain circumstances may well depend upon the view it takes of that argument.

In view of this situation it could hardly be expected that the Federation of British Industries would make a very much more forthcoming reply to the Chancellor than that of which we printed a report in last week's issue. It is too amorphous a body. In effect it seems to be saying more firmly than it says anything else that in a competitive world the firm which can offer the most value for the least money will have the highest chances of survival; that is, that it is up to the Government to see that conditions are competitive enough (though not too competitive !) to make price reductions worth while. The letter the Federation has sent to the Chancellor amounts in fact to a passing back, sympathetically, of the buck. Back to you, Derick ! Rightly so, of course ; the Government cannot escape its responsibility for keeping the national economy stable.

## AGRICULTURAL ENGINEERING EDUCATION

About a year ago, the Ministry of Education announced that it had been decided to establish a National College of Agricultural Engineering. The declared intention is that this college, which is to be built hard by the National Institute of Agricultural Engineering, in Bedfordshire, shall accommodate initially between sixty and 100 students from this country and overseas who will take courses leading to a diploma. As we pointed out, in our issue of February 20 last year, the Ministry's decision was reached only after protracted discussions with various bodies which had been emphasising the need for such a college for over three years. Those discussions convinced the Ministry that every effort to meet the growing requirement of fully qualified agricultural engineers must be made. But the interval between the announcement and the carrying out of a Ministerial decision appears to be a lengthy one, for there seems to be little visible sign of progress towards the setting up of this college. Undoubtedly, there are many matters of detail which have to be determined, but rather more expedition in bringing this technical education project to fruition does appear to be desirable. Owing to the tremendous expansion in farm mechanisation in the years since the second world war, agricultural engineering is a specialised subject which has become increasingly important in every country in the world. The food production of the world —a world which includes many under-developed territories—is to-day as much dependent upon the skill and effort of engineers as it is upon the good husbandry of farmers. In view of the high degree of agricultural mechanisation which has been achieved in this country, it would be a pity if future development was hampered by a deficiency in technical training and education facilities. Moreover, British agricultural machinery is finding its way all over the world. It is a valuable export. The knowledge of qualified agricultural engineers can be an even more valuable export in a day when increased food production is a prime essential in so many places.

## DIESEL-GAS-TURBINE COMBINATION

In the first paragraph of his paper entitled " The Diesel Engine in Association with the Gas Turbine " (read on January 20 before the Institution of Mechanical Engineers) Mr. Ernest Chatterton remarks that " The trend of present practice shows that the further development of the diesel engine is inevitably dependent upon its association with an exhaust-driven gas turbine." In the last paragraph he summarises his conclusions as follows : " It would appear that a highly supercharged two-cycle engine used as a gas producer feeding a turbine may provide an efficient and versatile power unit and merits serious consideration." Interesting indeed are the observations in which the author sets forth the results deduced from a systematic investigation of three basic systems whereby the diesel engine and the gas turbine may be combined to form a power unit in which the advantage of high charge pressures—either with or without charge cooling—can be realised. The investigation certainly appears to show that the two-cycle engine gives a better response to association with a turbine than does the four-cycle, " particularly at higher manifold pressures." While engine manufacturers and engine users cannot fail to take note of any arrangements whereby high specific power outputs may become practicable " without exceeding established limitations for maximum cylinder pressure, piston temperature, or turbine inlet temperature," they can be expected to proceed cautiously in the absence of actual operational experience of the equipments as applied in specific services. Considerable time has elapsed since the diesel engine was first used as a gas generator and the power taken from an exhaust-driven gas turbine. During this period there have been significant developments in respect of the fuel situation, developments which have influenced engine design notably in the case of large marine engines, where use is made of exhaust gas turbo-

charging combined with charge cooling and with precautions for avoiding difficulties arising from the burning of high sulphur fuel.

Valuable as is the publication of such indications as those upon which Mr. Chatterton has based the conclusions set forth in his paper, even more importance attaches to the publication of operational results enabling the potential user to assess the performance of the gas generator and turbine system in service. Such details must provide convincing evidence not only in respect of long-term operational reliability (often a major consideration), but as regards the overall economy when due allowance has been made for replacements, supervision and maintenance. There are, of course, sundry minor operational hazards apt to be common to all combinations and here it usually happens that the simpler the equipment and the fewer the gadgets the greater will be the likelihood of good routine performance. Service conditions differ, however, and power units must be provided for large ships, small ships, locomotives, electric generators, pumps, air compressors, &c. These services impose widely differing requirements, to say nothing of the facilities which may be required for emergency overhaul and replacements. It can sometimes prove no easy matter to decide as to which particular evil can best be tolerated and the engineer, while aiming at perfection, should be content if he attains something as far as possible on the plus side of mediocrity. What he now awaits is dependable information derived from actual running under service conditions comparable with those for which he himself must cater. Without the guidance afforded by such endurance tests it is hardly possible to predict just what may be the long-term response of the gas generator type of plant when operating with high air manifold pressures.

## AN INSTITUTION MERGER ?

At the time of the Institution of Civil Engineers' annual dinner, last May, we reported that Professor Pippard, who was at that time president of the Institution, had said that discussions were in progress about the possibility of amalgamating the Institution of Civil Engineers and the Institution of Municipal Engineers. Notice has now been given that agreement in principle has been reached between representatives of the two Institutions, as to the terms upon which such an amalgamation might take place. The full terms are soon to be submitted to members of both Institutions, and a postal ballot will be taken to decide the issue. Should amalgamation be decided upon, the Institution of Civil Engineers' charter will have to be amended, which is dependent on the approval of the Privy Council.

The two Institutions have clearly set about this proposal in a businesslike way, and have kept their members informed as soon as possible. A fairly long period of consideration is sometimes an advantage in such a situation and, indeed, should controversy develop, a meeting at either or both of the Institutions would clear the air. For our part, we would endorse the opinions expressed by Professor Pippard last year, when he said that the existence of a number of Institutions, all working towards the same ends, was no longer a source of strength and detracted from the influence which the engineer could bring to bear on the conduct of affairs. The amalgamation, he thought, might prove a pattern for other societies to follow. There are at least four other Institutions covering parts of the general field of civil engineering which would seem to fall within the professor's suggestion.

## PRESTRESSED CONCRETE

The Cement and Concrete Association's Prestressed Concrete Development Group recently organised an exhibition of prestressed concrete at the Institution of Civil Engineers, and also a day of lectures on prestressed concrete bridges. The latter proved so popular that it was repeated a week ago to-day. The exhibition, and the subject matter of the lectures, certainly indicated an encouraging activity, with considerable achievements ahead. Indeed, the Association states that while Britain did not originate prestressing, so enthusiastically has it been utilised that for the past ten years Britain has been leading the world !

The Association has been in the van of the enthusiasts. If the word " propaganda " had no baleful political overtones, but a purely beneficial meaning, it would adequately describe the Association's activities—lectures, training courses, and so on. It is interesting to speculate how much the rate of advance has been due to the intrinsic merits of the technique of prestressing and how much to this " propaganda." The talking-point amongst civil engineers seems to change every decade or so. Just after the war, it was possible to fill the main hall at the Institution—so we remember—merely by mentioning the magic words " soil mechanics." It looks as if the talking point of the 1960s will be traffic engineering. But prestressed concrete has undoubtedly been the great subject of the last decade, and judging from the popularity of these latest lectures, it is still very much to the fore. Which situation turns our thoughts again to the competition between steel and concrete touched upon in a leader last week when recent improvements in structural steelwork practice was discussed. The 1960s are likely to prove full of interest !

## The Engineer—100 Years Ago (JANUARY 27, 1860)

### " Aerial Messengers "

" Mr. Henry Coxwell, the well-known aeronaut, throws out a few suggestions to nautical men on the value of ' aerial messengers.' Let every ship, he says, be provided with an apparatus containing 1000ft. or so of compressed gas in a metallic receiver, the bulk of which need not be greater than a small cannon ; also a couple of miniature balloons of 500 cubic feet capacity. As the balloon is sure to go before the wind, a vessel approaching land, or grounded on a lee shore, will always be in a position to communicate by this contrivance. In the event of a vessel being burnt at sea, or of going down through springing a leak, the aerial messenger might convey the ship's fate and papers in a waterproof bag across the waves until the shore was reached or attention attracted from a passing sail. By filling only two-thirds of the balloon, space would be left for expansion, and the messenger, harnessed to the water by a float, would continue suspended for a considerable time."

### " Those English!"

" Some of the German Journals announce seriously that a company of English capitalists have made an application to the King of Naples for a concession for the extinction of Vesuvius. The principal seat of the fire of that volcano is situated several thousand feet below the level of the sea. By cutting a canal which would carry the water into the crater, the fire would be completely extinguished, and the operation, which would only cost 2,000,000 fr., would restore to cultivation land of ten times that value."

# Obituary

## HAROLD G. ALLEN

Harold G. Allen

We regret to have to record the death of Mr. Harold Gwynne Allen, M.A. (Cantab), which occurred in London, last Friday, January 22. Mr. Allen, who was eighty-five, was, until his retirement at the end of last June, a deputy chairman of W. H. Allen Sons and Co., Ltd., Bedford. He had devoted life-long service to the company, including a period of over fifty years as a director and, from 1928 to his retirement, as a deputy chairman. He was the father of Mr. W. Kenneth G. Allen, the present chairman of the company, and of Mr. H. Norman G. Allen, managing director, and was the third son of Mr. William Henry Allen, who founded the business in 1880. Harold Allen was educated at Westminster School and Trinity College, Cambridge, subsequently obtaining his engineering training at Queens Engineering Works, Bedford, and the Fairfield Shipbuilding and Engineering Company, Ltd., before being appointed to the staff of W. H. Allen Sons and Co., Ltd.

For many years Mr. Harold Allen was responsible for the administrative and commercial work of the company and he played a dominant part in the successful development of its world-wide organisation and business activities. He inherited many of his father's characteristics—foresightedness in business, thoroughness and directness in method, and a readiness to recognise and help initiative and enterprise among the young people in the firm.

Throughout his business life, Mr. Harold Allen endeared himself to the personnel of all sections of the Allen organisation, and the numerous associates who worked closely with him had ample opportunity of observing his qualities, both from the business and social points of view. It was always recognised in dealing with the problems associated with a large business that Mr. Harold Allen possessed outstanding tact and acumen. Every problem, large or small, received the fullest consideration before a decision was given. His determination and fairness, together with his charm of personality, won for him the sincere goodwill of all members of the organisation.

Mr. Harold Allen was also a well-known personality in all branches of the engineering and many other industries, as well as in Naval and Mercantile Marine centres and other different spheres. He travelled extensively for the purpose of furthering the interests of the company's business. Despite his advancing years, he maintained a keen and active interest in the firm's activities and was regularly at the London office up to his retirement.

One of Mr. Harold Allen's main interests was that of technological education combined with engineering training; it is true to say that he was personally instrumental in steering a course for the future careers of many engineers who are to-day holding important positions in all parts of the world. He was especially concerned, not only with the students' and apprentices' training and education courses, but also with their spare-time social activities, in particular the running of the Allen Boys' Club, which flourished for many years between the two world wars. An annual event which will always be remembered by numerous young apprentices and members of the Boys' Club was the outing to the Royal Tournament at Olympia, when they were the guests of Mr. Harold Allen for the day.

In his earlier years, Mr. Harold Allen made a notable contribution to the industrial life of Bedford and, in addition, he will be remembered in the town and county for his public-spirited service to the community in civic and other spheres, in particular, as the High Sheriff of Bedfordshire in 1925.

In addition to his normal business responsibilities with the company, Mr. Harold Allen also devoted much time and rendered valuable assistance to the work of a number of important bodies, including the council of the British Electrical and Allied Manufacturers' Association and the Grand Council of the Federation of British Industries. He was also a member of the Institutions of Civil Engineers and Mechanical Engineers.

Apart from his business activities, he had a deep love of music, art and literature, and also had a genius for being friendly and giving help and guidance. These attributes, together with his interest for the well-being of the company's junior employees, led to Mr. Harold Allen giving talks to the students and apprentices with a view to creating a real enthusiasm for life as the only way to the attainment of success.

Harold Allen never had a personality as strong as that of his brother, the late Sir Richard Allen; but in strength of mind and character he matched him. To the great benefit of the firm their interests were complementary as much as similar. Thus, while Sir Richard played an active part in the affairs of the Institution of Mechanical Engineers and was its president in 1928, and was equally active in other public ways, becoming very widely known and respected by engineers the world over, Harold devoted himself wholeheartedly to the business interests of the firm and the similar interests of engineering firms in general. Probably it was as much through his sagacity as through any one else's that his firm survived relatively less scathed than many others from the years of deep industrial depression of the 'thirties. Much less widely known than his elder brother, he was just as much respected by those who did meet him on business and on the councils of B.E.A.M.A. and the F.B.I., and his work for the firm was invaluable. Perhaps his outstanding service to the firm was to bequeath to it two sons in whose hands, primarily, its fortunes now rest.

## A. J. PARROTT

We regret to have to record the death of Mr. Arthur John Parrott, which occurred on January 13, at the age of seventy-four. Mr. Parrott was joint managing director of Heat and Air Systems, Ltd., on the board of which company he had served since its inception in 1935. He spent the whole of his working life in the business of heating and ventilating engineering, serving his apprenticeship with Ashwell and Nesbitt, Ltd., Leicester. On the completion of his apprenticeship, Mr. Parrott joined the staff of the United Kingdom branch of Buffalo Forge Company and subsequently held appointments with Sturtevant Engineering Company, Ltd., and Carrier Engineering Company, Ltd. For a short time prior to the formation of Heat and Air Systems, Ltd., he was on the London office engineering staff of Controlled Heat and Air, Ltd.

## R. W. HARRIS

We have learned, with regret, of the death of Mr. R. W. Harris, which occurred suddenly on January 13. Mr. Harris, who was fifty-three, was a director and general manager of Aircraft Steel Structures, Ltd., Acton, a subsidiary of Simms Motor and Electronics Corporation, Ltd.

Mr. Harris was born in Coventry and educated at the Bablake School there and subsequently at Coventry Technical College. He then served an apprenticeship with the M.L. Magneto Company, which was afterwards absorbed by Joseph Lucas and Co., Ltd. In 1946 Mr. Harris joined Bryce Berger, Ltd., and was largely responsible for this company's development of fuel injection and starting equipment for diesel engines.

Mr. Harris joined Aircraft Steel Structures, Ltd., as director and general manager, in April, 1958, when that company was acquired by Simms Motor and Electronics Corporation, Ltd.

# British Machine Tool Industry

*A memorandum by Mr. Austen Albu, M.P., was circulated to Members of the Parliamentary Labour Party's Trade Union and Economic groups before the recent General Election. We print it almost in full below.*

FOR some time the machine tool industry has been among those tentatively included in the Party's programme for nationalisation. Apart from trade union pressure, the reasons for this are based on criticisms made of the industry over a long period by engineers and economists. This memorandum is an attempt briefly to examine the industry and the criticisms made of it and to suggest ways in which a future Labour Government might deal with them.

### Criticisms of the Industry

The main criticisms of the industry are that its output and exports are inadequate and that it is technically backward.

In 1935 value of output was £6,500,000 ; by 1957 it had risen to a peak of £95,000,000 (excluding woodworking tools). Allowing for a three-fold increase in price this is a nearly five-fold increase in volume. Exports, however, had only risen from £4,500,000 in 1938 (of which the U.S.S.R. took £1,700,000) to £28,000,000 in 1957 ; an approximate doubling of volume, compared with a five-fold increase for other branches of the engineering industry (including motor vehicles). During this period total recorded world exports appear to have risen a little over three times in value (i.e. remained stationary in volume) ; but post-war figures exclude Eastern Europe and China. Most of these exports are to countries at an earlier stage of development than this country, who will, in time, make some of their own machine tools. Before the war, Britain's share of world trade in machine tools was 7·1 per cent compared with Germany's 48·3 per cent and U.S.A. 35·3 per cent. Switzerland had reached 5·3 per cent with her highly specialised tools. The following table shows the shares in recent years of the major exporting countries, excluding those in Eastern Europe and China :

| | 1953 Per cent | 1955 Per cent | 1957 Per cent | 1958 Per cent |
|---|---|---|---|---|
| U.K. ... ... | 14·6 | 15·8 | 15·3 | 14·2 |
| W. Germany | 23·8 | 26·7 | 30·5 | 31·9 |
| U.S.A. ... | 33·5 | 28·3 | 26·9 | 25·7 |
| Switzerland... | 11·2 | 15·9 | 13·4 | 14·0 |

The Western Germany share is less than that of pre-war Germany as a whole, but the level of East German production is not known. Russia and Czechoslovakia are also large manufacturers and the latter always a substantial exporter. Reports of the mass production of machine tools by the use of transfer machines in Russia indicate a serious future competitor.

In spite of the increase in production, imports have also risen substantially. During the rearmament period they reached £60,000,000 in one year and in 1957 were £21,750,000. The industry was for years content with a delivery period of two years, and started squealing when this was reduced for some types to six months. Mr. William Hornby in his volume "Factories and Plant" in the *History of the Second World War*, draws attention to the growing dependence of the U.K. before the war on imports of many types of machine tools, especially for mass production. Although many types previously imported are now being manufactured, often under licence, this remains true to-day.

When one turns to the level of technical advance of the industry, it is significant that what is lacking in British production is frequently those types which reflect design leadership. Britain tends to sell weight and import refinement. This arises partly from the fact that the largest manufacturers are also importers ; but it is also the result of the quite inadequate attention paid by the industry to research and development and the employment of scientifically trained engineers. According to the Report on "Scientific and Engineering Manpower in Great Britain, 1959" (Cmd. 902), scientists and engineers represented 1·3 per cent of the numbers employed in the industry. This corresponds to the low figure for the mechanical engineering industry in general and is much less than in electrical engineering, constructional engineering, precision instruments and, of course, aircraft. Even these figures are, however, misleading. More than half the scientists and engineers in the machine tool industry qualified by becoming corporate members of a professional institution. Many of them are members of the Institution of Production Engineers, which for many years admitted members without examination. Others will have qualified by obtaining a Higher National Certificate by part-time study. It is generally recognised that for really advanced work in research and development a university degree or its equivalent is required to-day. Although the figures are not separately available it is thought that the industry employs few university graduates. It has been estimated that the German industry recruited about 500 graduates in 1958 while the British industry recruited two. The expenditure on research and development in 1955 was 1·1 per cent of net output compared with an average of 2·0 per cent for all industries except aircraft.

This is particularly serious in an industry where technical demands are increasing rapidly (e.g. higher speeds and feeds due to growth of use of hard metal cutting tools and the application of electronics and automatic operation). Few universities in this country have departments dealing with machine tool design. An exception is Manchester College of Science and Technology at which the industry has been shamed into giving a number of so-called post-graduate scholarships for designers. There is nothing to compare with, for instance, the magnificent laboratory at the Technical University, Aachen, and certainly nothing to compare in the research field with the works of the E.N.I.M.S. (Experimental Scientific Research Institute for Machine Tools) in the U.S.S.R. The director of E.N.I.M.S., in a recent study of Western machine tools, rates British tools considerably below corresponding American and West German tools in cutting speeds and feeds.

### Market Potentialities

The industry is a very suitable one for British exports. Its products have a high conversion factor ; the labour employed is highly skilled and development and design should involve the employment of scientifically-trained staff. It can be organised in units of medium size. It does not involve the use of capital in very large blocks, so that there need be no great concentration of economic risk in its expansion.

Although many mass-production types of machine tool are imported from U.S.A., competition in world markets is more likely to be felt in the immediate future from Germany, Switzerland and, in the not so distant future, from the U.S.S.R. and other Eastern European countries. The U.S.A. may well be pricing itself out of the market.

There are three ways in which the industry might develop ; none of them exclusive :

(*a*) The production of very advanced types embodying revolutionary changes, in relatively small quantities. The competitive advantage here would depend entirely on scientific research and development.

(*b*) Mass-produced, cheap general purpose machines. These might enable us to maintain sales in under-developed countries starting up their own industries. One British firm is reported to have been considering operating along these lines.

(*c*) The mass production of units suitable for assembly into a wide range of machines of all types. This is the system developed by Renault and copied by British Motor Corporation for making transfer machines. It is being developed on a very extensive scale in Russia and could lead to a substantial revision of the capital/labour ratio in many branches of the engineering industry. Here the scale of production may be a limiting factor for the British industry unless it is able to take advantage of a common market or make co-operative arrangements with European firms.

Without further and much more detailed inquiry, which has certainly not been undertaken by the industry, it is not possible to say which of these lines is the most promising.

### Recommended Policy

The essence of the proposals set out below is a sequence of steps, the earlier ones involving little risk of violent opposition and no great expenditure, each step providing an indication as to whether the next is desirable. It also takes into account the fact that the industry is mostly composed of a number of small firms of differing quality, but intimately linked with other industries at home and abroad.

Basic to the proposals is the creation of a cadre, or organisational framework, which could successively take up new responsibilities as its powers were increased. The first stage would be to establish a central research organisation responsible in the first place for undertaking an extensive market and product research programme to determine the lines of technical research and development which the industry should pursue and the gaps in its output most needed to be filled. Such a study has certainly never been made, although the contents of the D.S.I.R. Report are not known. This type of inquiry is recommended by Professor Seymour Melman in his report to the European Productivity Agency.

Whilst this was being done, the organisation should be establishing a research and development division and the second stage would be for it both to carry out research itself and to farm out development contracts to some of the better machine tool firms. At this stage the existing Production Engineering Research Association might be absorbed. Alternatively, the buildings and equipment of an ordnance factory might form the nucleus of the establishment.

The third stage would involve the establishment of a prototype and small-scale manufacturing unit ; to manufacture under

ideal conditions some of the products of the research division. Manufacture of other products might be sub-contracted to private firms in which Government funds might be invested in accordance with Labour Party policy. In any case the organisation would become the natural body to advise on Government investment in the industry.

The fourth stage would involve the setting up of a marketing branch which would be responsible for selling the products of this research at home and abroad.

It is essential that the work of these four branches of the organisation should be closely linked so that responsibility for the success of the undertaking would be fully shared between the marketing and development branches and production suitably planned. The technical division should cover a wide range of disciplines ; machine tools embody mechanical, metallurgical, electrical, electronic, hydraulic, chemical, mathematical and many other factors, and it is in failing to recognise the possibilities offered by alien experience that the industry's failure has been most marked.

No attempt should be made to make the organisation a paying concern immediately. It should be treated like the National Research Development Corporation, and not expected to break even for a term of years ; although its marketable products should be sold at economic prices, bearing their own share, and no more, of development costs.

Although the final investment in such a programme might be considerable, no heavy expenditure need be incurred until the requirements are known. The first market and technical research studies could be sub-contracted while the staff of the organisation was being built up.

As a final stage, the marketing division might take over the whole of export marketing of machine tools from this country. There would be advantages in such an export agency with substantial resources. These advantages will grow as our customers overseas become more and more centralised or Government buyers, and expect to be supplied with complete, fully equipped, plants or factories. Already this is happening in, e.g., India, where British firms are setting up plants, and the Russians are offering plants in this way. There are, however, very few organisations in the engineering industry in this country able to undertake this work.

The methods by which the industry markets its products at home have been criticised (e.g. by Beesley and Troup in the study published by the National Institute for Economic and Social Research) on the ground that the system of sole agencies, each handling a variety of different types of tools each of a single manufacturer, hinders the growth of innovation. The existence of a Government sponsored development and marketing organisation, handling new products, would help to overcome this disability.

# Control and Instrumentation of a Marine Reactor

*A paper by R. Anscomb* and F. Hutbert†, on the control and instrumentation of a marine reactor was discussed at a meeting of the Joint Panel on Nuclear Propulsion, at the Institute of Marine Engineers, London, on January 26. Because the systems discussed are still in an early stage of development the authors attempted little more than to outline the nature of the problem and to indicate possible solutions in particular cases. They also gave a general description of a typical control and instrumentation system which might be used in a ship. Abstracts from the paper are reproduced here.*

THE requirements of the reactor control system may be defined as :

1. To maintain the designed reactor temperature and pressure conditions during steady state operation.

2. To effect changes in reactor power output to meet changes in demand without causing excessive variations in reactor temperature and pressure conditions.

A marine reactor is a complicated piece of precision machinery which must be designed to give the maximum practicable power/weight ratio. This means that all its components must work close to their safe metallurgical limits during steady state operation. To do this safely the reactor must be provided with a control system so precise and reliable that none of the components will be subjected to excessive temperature and pressure variations during normal changes in power or as a result of minor faults and accidents.

[The authors then discussed the influence of the flux/power relationship ; temperature coefficients of reactivity ; density, void and power coefficients ; and the effect of depletion and poisoning.]

An indirect cycle reactor installation may be said to comprise the reactor, the main coolant blowers or pumps, and the main heat exchangers on the primary side ; and the main heat exchangers, propulsion turbines, ship's auxiliaries and possibly a dump condenser on the secondary side.

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† Reactor Physicist, Development and Engineering Group, United Kingdom Atomic Energy Authority, Risley.

## Control Programmes for Typical Reactor Installations

*1. Liquid-Cooled Systems (Non-Boiling).*—The density, specific heat, and other heat transfer characteristics of liquids normally used for reactor cooling are such that the temperature rise through the core is small, so that the problem of controlling the reactor inlet temperature to avoid overheating of the primary circuit does not arise.

Due to the small difference (say 20 deg. to 30 deg. Cent.) between the reactor inlet and outlet temperatures it is convenient to programme a liquid-cooled reactor power plant to maintain a constant average coolant temperature in the core. The reason is that liquid-cooled reactors have large negative temperature coefficients and such a programme involves the least amount of external control.

Constant Average Temperature Programme.—In a liquid-cooled reactor having large temperature and density coefficients working on a basis of a constant primary coolant flow and average temperature, the sequence of events following a demand for increased power is, briefly, as follows :

1. Opening of turbine throttle valve and withdrawal of steam from heat exchanger.

2. Fall in reactor inlet temperature of primary coolant.

3. Fall in average primary coolant temperature and consequent increase in reactivity.

4. Rise in reactor power increases temperature of fuel and hence reactor outlet temperature.

5. Restoration of average primary coolant temperature to original figure at new power level.

A slow xenon effect will follow, necessitating minor adjustment of control rods. Thus a non-boiling liquid-cooled system operating on this programme is load following. This feature is exploited to good advantage in the highly enriched pressurised water reactors used in submarines. In the more economical lowly enriched systems, this self-regulating effect is not so marked due to the Doppler broadening effect on the temperature coefficient of the fuel. Such systems can be self-regulating for limited power variations but control and manipulation is usually necessary for changes in excess of 20 to 30 per cent.

The Constant Reactor Outlet Temperature Programme (Fig. 1).—Briefly, the sequence

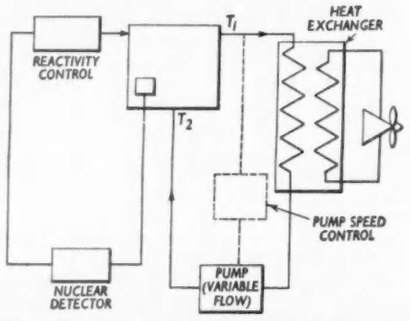



**Fig. 1—Block diagram of control system for obtaining constant outlet temperature programme**

of events following a demand for increased power is as follows :

1, 2 and 3 as above.

4. Increased fuel temperature attempts to increase reactor outlet temperature.

5. External control measures coolant outlet temperature and keeps it constant by varying the coolant flow.

6. External control inserts reactivity absorbers to compensate a little for additional reactivity introduced by lower average coolant temperature.

A comparison of these two programmes emphasises the great advantage of the average temperature programme from a control point of view. Its additional advantage is that it maintains a nearly constant volume of liquid in the primary circuit and thereby permits the use of a minimum sized pressuriser. The disadvantage of both programmes discussed is that they cannot prevent changes in steam pressure over the power range, with its consequent effects on turbine design, pipe sizes, and boiler feed pump and dump condenser control problems.

Irrespective of the inherent load following properties of a reactor installation, adjustable reactivity absorbers must always be installed to provide compensation for the losses of reactivity due to depletion of fuel and fission product poisoning effects. Some means of meeting this requirement are discussed later in the paper.

The Constant Steam Pressure Programme.—Another alternative is to hold the steam pressure constant and allow the primary

coolant temperature to vary. This permits optimum design of the steam plant but raises difficult reactor control and pressuriser design problems to deal with the changes in reactivity and primary coolant volume dependent on the changes in average temperature. In addition, the control system must be designed to compete with the natural tendency of the reactor to work to a constant average temperature programme. A more practicable solution is described below.

A Possible Compromise Solution for a Pressurised Water Reactor System.—A possible compromise solution that has the advantages of both a constant reactor coolant temperature programme and a constant steam pressure programme, takes account of the time constants involved in effecting power changes.

An elementary plant and control system which might be designed to provide such a programme is indicated in Fig. 2. It is

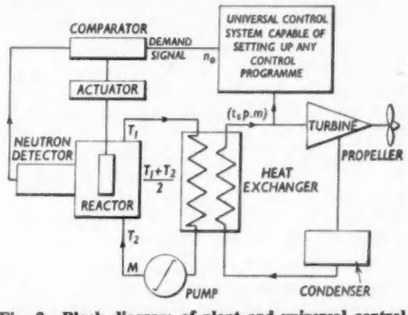



**Fig. 2—Block diagram of plant and universal control system capable of setting up any type of control programme**

assumed that, irrespective of any instantaneous demands for change by the various parameters, the control system is designed such that the reactor power demand signal cannot change at greater than a specified rate, e.g. 3 per cent to 100 per cent full power in less than a minute.

Now let us examine some of the typical demands that might be made on this system. If the installation is operating at low power and the throttle is opened slowly, e.g. in some minutes, the demand signal ($n_0$) will rise slowly and cause the nuclear loop to reposition the control rods so as to match ultimately the constant pressure reference demand. Suppose now that the throttle is opened instantaneously. No new signal comes into the comparator instantaneously from the demand loop because of the velocity limit imposed on $n_0$. However, this quick throttle change is reflected through the boiler into the primary loop as a change in average temperature of the reactor coolant, and the negative temperature coefficient supplies a change in reactivity to match the load for a short time. In other words, for transient throttle operation the plant behaves initially as though it were operating without controls on a constant average temperature programme stabilised only by the negative temperature coefficient. Ultimately a demand signal is received by the comparator and the entire system slowly changes over to a constant pressure programme.

The system responds to a change in reactivity in the reactor in a similar manner. If this reactivity change is a slow one, such as is caused by depletion and poisoning, the ($n$) loop signal, which is also likely to be velocity limited by virtue of the fact that the control rods are not permitted to change reactivity very fast, will handle this change slowly and safely. If a fast change in reactivity occurs, the negative temperature coefficient again takes over and the system behaves temporarily as though no external controls were present. This means that by proper design the control system of a non-boiling liquid-cooled reactor which is not subject to an upper limit on the coolant outlet temperature (e.g. a pressurised water reactor) can have the advantages of both constant average coolant temperature and constant steam pressure. This advantage is, however, gained only by the provision of a more complicated external control system.

[The authors then examined the particular requirements of the organic moderated reactor.]

*II. Liquid-Cooled Systems (Boiling).*—In a boiling reactor using natural circulation, as the moderator boils its density fluctuates and thus affects neutron moderation and leakage ; so the power level will fluctuate and the permissible output tends to be limited by the maximum steam void fraction with which smooth operation can be achieved. Further, with such a reactor a certain increase in load increases the steam flow and reduces the pressure and hence causes more of the moderator to flash into steam. This causes the flux power to fall, necessitating control rod adjustment to meet the increased demand. Since control rod movement is necessarily slow, the boiling reactor cannot be regarded as load following in relation to sudden changes of demand.

This control problem can be reduced significantly by the adoption of a dual cycle in which a proportion of the reactor heat is used for heating pressurised water. Such an arrangement results in a considerably smaller proportion of the reactivity being held in the steam voids and hence in better stability and load following characteristics. Thus a dual-cycle boiling water reactor is a cross between a pressurised water reactor and a boiling water reactor in that a proportion of its output is in the form of high-pressure steam taken directly from the reactor to the turbine and the remainder in low-pressure steam taken from heat exchangers heated by the pressurised water loop. Thus, by suitably balancing the direct steam production and the sub-cooling in the core, it should be possible to obtain some of the thermal efficiency advantages of the boiling water reactor in conjunction with the good load following and other control characteristics of the pressurised water reactor.

For operation in a marine environment, however, there remains the question of the extent to which movement of the ship will affect the movement of the steam voids and thereby the reactivity. Whereas this movement is unlikely to result in any instability, it may cause such power oscillation as to create unexpected temperature transients in the system.

[Next the authors considered the control requirements of gas-cooled reactor systems.]

## Instrumentation for Safe and Effective Control

At this relatively early stage in the development of reactor systems it is necessary, at least with prototypes, to install as many measurement channels as is practicable in order to make the best use of the experience gained from the reactors that are operating.

The suggested requirements of a marine reactor control and instrumentation system are :

1. To provide for automatic load following in the power range and for manual control during start-up and normal shut-down.
2. To provide information for the auto-control system, reactor protection system, and operating personnel.
3. To take protective action against damage to the installation arising from malfunctioning or maloperation.
4. To provide radiation monitoring system.

To meet these requirements, numerous measurements must be made, including :

I. Neutron flux internal and external to the core.

II. Temperatures of the fuel, fuel cans, moderator, coolant and core structure.

III. Coolant activity to detect and locate defective fuel elements.

IV. Radiation in the containment space, controlled areas, and other parts of the ship.

V. Radiation from ventilation, waste gas and aqueous waste discharge systems.

*Power Measurements.*—The distribution of flux is approximately constant over the power range. In a cylindrical " unflattened " reactor it is approximately a cosine curve in shape axially and a Bessel function of zero order ($J_0(x)$) radially. Further, as already mentioned, the thermal power of a reactor is approximately proportional to the neutron flux. Thus, flux measurements may be used to provide information and to control power.

Safety demands that the neutron power be monitored at all power levels from shut-down to full power. It is normal to install an artificial neutron source to provide a shut-down power of approximately 1W with a freshly fuelled core. The shut-down power will be higher than this after the reactor has been running at power, especially in reactors containing heavy water or beryllium where photo neutrons are produced by the interactions of gamma radiation on these elements. For a hypothetical marine reactor with a maximum thermal power of 100MW, the range of power is thus 8 decades, and a measuring system covering 9 decades would probably be installed to provide adequate coverage (e.g. 0·2W–200MW). It is impossible to cover this range with one instrument and the different instruments required are described below. Each range overlaps the adjacent ranges by at least a decade.

Source Range.—This channel might be designed to cover the range 0·2W–2·0kW and has to discriminate neutron flux in a background of comparatively high gamma radiation. There is a choice of two types of detectors (the fission chamber and the $BF_3$ counter) and both can be employed with pulse counting equipment. This equipment can discriminate between the pulses due to gamma radiation, which are of smaller amplitude than those due to neutrons. The $BF_3$ counter has the better sensitivity to neutrons but cannot function as effectively in high gamma fields and at present its operative temperature is limited to about 100 deg. Cent. The fission chamber can operate in gamma fields up to $10^8$R per hour, and types are being developed to work at temperatures of up to 450 deg. Cent. A typical size is 1in diameter by 6in long. The associated equipment would consist of a head amplifier, main amplifier, discriminator, log ratemeter, and possibly a period meter. The head amplifier has to be located adjacent to the detector but the remainder may be sited in the control room or its adjacent instrument space.

Intermediate Range.—This channel might, typically, cover the range 200W–20MW, for which gamma compensated, boron lined, d.c. ionisation chambers are the best choice. It is possible to use uncompensated chambers in large land-based graphite reactors by siting them in thermal columns and using thick lead shielding to reduce the gamma radiation. In compact reactors, however, space limitations preclude the shielding of the chambers, which are themselves some

3½in diameter by 8in long. Stainless steel ionisation chambers are now made which will operate at up to 450 deg. Cent.

High Power Range.—For the high power range covering, say, 200kW–200MW, uncompensated boron lined d.c. ion chambers are satisfactory, although in water or organic moderated reactors where the neutron flux is attenuated more heavily than the gamma radiations, the compensated chamber may have its advantages.

The equipment associated with a d.c. ion chamber consists of a head amplifier, log d.c. amplifier, log power recorder, rate of change circuits, doubling time recorder, and indicator, of which only the chamber and head amplifier need to be adjacent to the reactor. A linear drift recorder is also provided.

Rate of Change of Flux.—Safety on exponentially rising fluxes is achieved by period meters which by suitable circuitry prevent the reactor period from shortening below a predetermined value by tripping the reactor. Period meters are normally only used in the low power range where flux changes over decades are possible without increases in temperature.

Temperature, Flow and Pressure Measurements.—Temperature measurements are made by means of thermocouples distributed around the circuit. At present, large numbers are necessary to determine the detailed performance of fuel elements, temperature distributions in moderator, coolant and shielding, and stresses in the primary circuit. In land-based stations the numbers are such that a data processing machine is required to read and record them. As the technology develops the number should fall from the hundreds used in some current designs to a more manageable figure. Safety is achieved by initiating a reactor trip if some temperature exceeds a predetermined value.

Flow measurements can be made by venturi, Dahl, or similar meters. The great advantage of flow measurements is that in common with those of flux they have a very fast response time. By combining flux and flow measurements an approximate measure of temperature rise in the core can be obtained with a much shorter delay period than is associated with temperature measurements.

Pressure measurements form a vital part of the safety circuits of a reactor. This is because the worst reactor accident conditions can arise from a breach of the primary circuit, the first indication of which would be given by instruments measuring the rate of change of coolant pressure. Consequently reactor trip circuits are associated with pressure and rate of change of pressure measurements.

[The authors also set out the general requirements of safety systems and faulty fuel element detection.]

*Flux Distribution Measurement.*—In addition to their nominal function, control rods may be used to hold down the initial excess reactivity needed to give a reactor core the required life of two to three years between refuellings and to "flatten" the core and thereby ensure more uniform burn-up of the fuel. If the rods are to be properly programmed flux measurements must be made at intervals of a few months. These can be made by three methods, viz :

1. The temporary insertion of a wire at selected points in the reactor and measurements of its gamma activity after withdrawal.

2. Measurement of the release of fission products from uranium wires situated in the reactor. Coolant is drawn over these wires and then led to a moving wire precipitor unit where the fission products are measured.

3. Calculation of fluxes from temperature and flow measurements.

The third is believed to be most practicable.

## Special Design Requirements in a Marine Environment

The special design requirements which may be necessary to ensure that a reactor control and instrumentation system will operate satisfactorily in a marine environment include the following :

*Special Reactor Core Design.*—The refuelling of a nuclear reactor is a complicated process. Such an operation undertaken at sea must inevitably be more difficult and dangerous than on land, since movement of the ship is potentially liable to create faults in equipment and result in accidents to personnel. For this reason it seems desirable to design marine reactor cores so that they require refuelling only at infrequent intervals, e.g. of the order of a year or more. To meet this requirement it is necessary for operational reasons to build in considerable excess reactivity and for economic reasons to provide some form of "flux flattening" to achieve uniform burn-up of the fuel. This can be achieved in a number of ways, e.g. :

(*a*) By investing additional reactivity absorption in control rods and programming the positions of these to provide the flux flattening.

(*b*) By the introduction of poisons or diluents into the moderator during the early stages of the core life and the programmed withdrawal of these as fuel depletion and fission product poisons build up, combined with fuel lattice pitch variation for flattening.

(*c*) By varying the fuel lattice pitch across the diameter of the core to achieve flattening and using control rods for reactivity holddown only, giving a more evenly balanced distribution of reactivity control over the core than with (*a*).

(*d*) By the use of "burnable poisons" fitted at suitable points in the core.

The disadvantage of (*a*) is that initially the rods near the centre of the reactor must be inserted deeply into the core to provide the flattening effect. This implies severe distortions of the neutron flux and a possible requirement for special and very expensive control rod materials which will remain effective for long periods under the intense neutron bombardment. The great virtue of this method is that it provides facilities for adjustment of the distribution of reactivity throughout the core life. The disadvantage of (*b*) is the problem of removing effectively the poisons from the core after they have performed their function, without leaving any surface contamination that might reduce the overall reactivity of the reactor. The exception to this may be the use of a heavy water diluent in a light water reactor which produces what is known as a spectral shift. Engineering difficulties may be involved in a design incorporating (*c*) but the scheme is worthy of investigation.

At first sight (*d*) appears attractive but the problem of suitably siting and concentrating the poisons to take account of variations in flux throughout the core life presents difficulties. It is believed that to date (*a*) is the only one sufficiently developed for immediate use.

*Reactor Shut-down Arrangements.*—The reactor shut-down arrangements should be capable of shutting down the reactor up to the angle of list of 90 deg. In addition, they should operate automatically when the ship either becomes submerged or heels to an angle in excess of 50 deg. The arrangements should be capable of keeping the reactor shut down irrespective of the attitude of the ship without limit under all foreseeable operational and accident conditions. Effective shut-down should not be impaired by structural distortion of the pressure vessel or core.

*Control Positions.*—All necessary controls and instrumentation should be arranged to permit control of the reactor installation from outside the containment structure. In addition to, and remote from, the normal reactor control room, an emergency shut-down position from which the reactor can be shut down and its condition monitored should be provided.

*Operating Conditions.*—All reactor controls, protective devices and instrumentation should be designed to operate satisfactorily under all conditions of rolling, pitching, heaving and a permanent list of 50 deg. They should also be so designed and/or mounted as to withstand without loss of accuracy the vibration, accelerations and shock loadings encountered at sea. Figures of $1g$ to $1{\cdot}5g$ and $3g$ to $5g$ in any direction for ramp and shock accelerations may be regarded as a working basis for the design. Finally, the systems and their components must either be insensitive to climatic variation or accommodated in air-conditioned compartments. Where air-conditioned compartments are essential the plants should be duplicated.

*Manœuvrability.*—Where limitations on the rate of change of reactor power unduly restrict the flexibility of propulsive power, arrangements should be provided to ensure that under all normal operating conditions adequate propulsive power is available to maintain good manœuvring characteristics.

*Reliability and Maintenance.*—The systems and their components should always "fail to safety" and be incapable of hazarding the reactor by maloperation or by abnormal motion of the ship.

To meet the above requirements it will be necessary to redesign certain elements of current land-based reactor instrumentation (e.g. chart recorders) and it may also be necessary to introduce transistor switching devices on a fairly large scale. In addition, with any reactor system there will almost certainly be an initial requirement for a dump condenser system. With some systems it may be necessary to provide steam dumping facilities covering the whole power range, but in others, e.g. those with significant negative temperature coefficients, a condenser capable of handling, say, only 20 per cent of the full power steam may be adequate. In the latter event it may be found practicable to use the ship's main condenser in association with a suitable desuperheater for the purpose.

*The Dump Condenser.*—The arrangement illustrated in Fig. 3 shows a typical layout of a dump condenser and its associated control mechanisms integrated into a reactor system. If the ship is steaming steadily, all the steam generated other than that required for auxiliary use is passing to the main engine. When the main engine power is reduced, the rise in steam pressure at the pressure sensing device actuates the main dump valve and the variation in quantity between steam demand and steam generated is dumped to the dump condenser. Full standby capacity is provided for both the sea water circulation of, and feed water extraction from, the dump condenser. Inherently there is little that can go wrong with such a condenser so only one unit need be fitted. If, however, through a concurrent combination of fault conditions, the

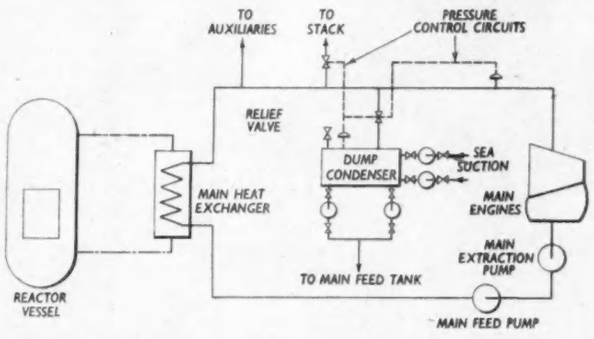



**Fig. 3—Typical steam circuit incorporating a dump condenser**

pressure in the dump condenser should rise sufficiently to endanger the structure of the condenser, then excessive pressure sensing elements would cause the dump valve to close and open the steam line to atmosphere. The atmosphere can be regarded as the final heat sink and an acceptable standby to the dump condenser.

Positioning of the pressure sensitive device actuating the master dump valve will depend on whether a constant pressure is required at the main engine stop valve or at the steam drum.

In certain installations, such as the American ship "Savannah," the main condensers may be adapted to perform both the normal duties of a condenser and also the duty imposed by steam dumping requirements.

*Irradiation Data.*—If control rod programming is found necessary to ensure a high burn-up of all fuel elements and thereby more economic propulsion, the instrumentation will be required to give irradiation information. This may imply the recording of a large number of flux or temperature and flow measurements in the various channels in such a way that the information may be transmitted to a shore base for feeding into a suitable computer. Such a computer could calculate the optimum control rod positions for subsequent reactor operation which could be communicated by radio to the ship.

### Future Design and Research

From the preceding paragraphs it will be noted that the control and instrumentation systems for current reactor installations comprise mechanisms which must be designed and built to the standards of precision instruments. Electronic equipment and its associated circuits are required on a scale which is paralleled only by the control systems for guided missiles and other modern military weapons. For this reason, the problems associated with its installation in a ship are comparable with those encountered in the installation of armament in a modern warship.

The major difference between a modern warship and a merchant vessel in this respect lies in the number and diversity of qualifications of the crew. The provision of a highly specialised staff for the operation and maintenance of the reactor installation of a nuclear merchant ship on the scale required for comparable work in military vessels would involve a quite unacceptable economic burden. For this reason it is of paramount importance that current and near future control systems should be designed and built to the highest standards of reliability and so fitted with built-in duplicate components as to ensure the minimum of maintenance by the ship's staff. In addition, they must incorporate such data processing equipment as is necessary to allow only one or perhaps two reactor operators to control the plant safely and efficiently. This may imply considerable capital expenditure but is the only practicable line of attack at present.

As a longer term measure, a reduction of the complexity of the system should be aimed at by such means as :

1. A statistical evaluation of the reliability of the various components with a view to a reduction in the number of standby units.

2. A critical examination of the scale of temperature, flux and flow measurements with a view to their reduction.

It will be appreciated, however, that the rapid development of nuclear propulsion depends largely on the maintenance of an accident free record. For this reason it would be most unwise to adopt any simplifications of control and instrumentation systems, however attractive economically, before extensive experimental work and operational experience had proved them to be acceptable. As knowledge of reactor technology and kinetic behaviour increases it will be possible to make corresponding reductions in the scale of instrumentation and safety circuits but significant improvements should not be expected for some years.

Probably one of the most fruitful lines of development at the present time is in data processing equipment to handle the vast number of measurements to be made and present them in digestible form to the operator. A second possible line is towards the replacement of relays and electronic valves by transistors and similar solid state devices.

### Acknowledgments

This paper is published with the permission of the Atomic Energy Authority but it should be taken to represent only the views of the authors and not as an indication of Authority policy in any respect.

The authors desire to acknowledge that certain of the diagrams have been derived from *Control of Nuclear Reactors and Power Plants* by Schultz, and NAA-SR-3859 *Maritime Organic Moderated and Cooled Reactor* published by the U.S.A.E.C.

## Computer Discussion Meeting

A two-day discussion meeting on "The Reliability and Maintenance of Digital Computer Systems (Managerial and Engineering Aspects)" was held at the Institution of Electrical Engineers on January 20–21, under the ægis of the British Conference on Automation and Computation. Sessions 1 to 3 on January 20, arranged by the British Computer Society, Ltd., comprised discussions on the reliability of organisational procedures, improving reliability by programming strategy, and maintenance and fault-diagnostic techniques. Each session was introduced with short papers serving as a basis for discussion. In an account of preventive maintenance procedures on a computer given by R. P. Gibson and E. H. Lenaerts, of Leo Computers, Ltd., it was stated that the policy had been directed towards the detection of all components which were deteriorating towards the failure point and for their replacement before operational failure occurred. This left only catastrophic faults to be dealt with during operational time. In practice it had been found that the application of this policy allowed at least 95 per cent of this time to be free from technical troubles. Every part of the computer was tested daily under functioning conditions by the use of a suite of test programmes which were run with the simultaneous application of marginal voltages. Used with the marginal-test system, the test programmes enabled the area of a faulty component to be isolated within a few seconds. The marginal-test system not only gave early warning of deteriorating conditions, but also allowed the degree of deterioration to be assessed so that appropriate action might be taken. Special attention was regularly paid to the most vulnerable electronic components, i.e. valves. This was necessary in order to avoid a high inefficiency when a computer had matured such that a regular number of valves was dying of old age. Valves were removed from the computer for testing when they had served a certain period, the length of which was determined by the kind of valve. Those valves which passed the test were declared fit for further service in the computer for a specified time before requiring another test. It was considered necessary to test all new valves before insertion into the computer in order to prevent potential computer failures due to valves having intermittent leakage.

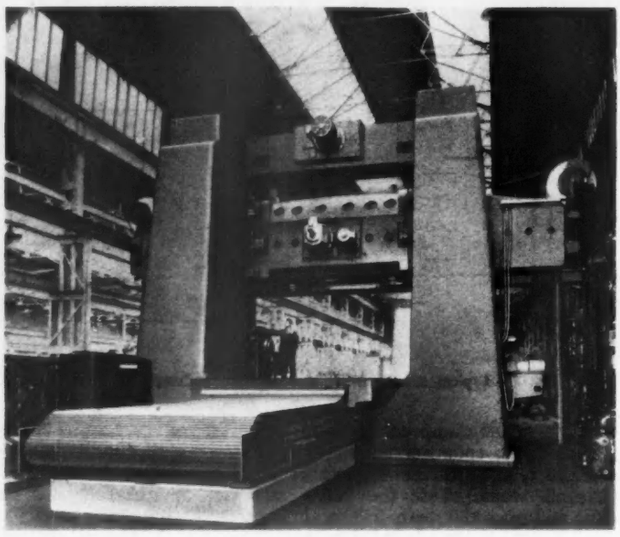
During the sessions on January 21, arranged by the I.E.E., discussions were held on the influence of engineering design on reliability. A contribution by Dr. A. A. Robinson and Mr. R. E. Hodgkinson, of Ferranti, Ltd., said that the stage had been reached where computer users were developing their own ideas of what was required, so that designers had to be constantly investigating novel techniques. However, well-proved techniques should not be abandoned, and to-day the plug-in unit principle came in this category. This enabled close-packing of components to be combined with good accessibility. It could lead to cooling problems, and although forced cooling was noisy and tended to choke components with dust, in many cases there was no alternative. The need for forced cooling should be foreseen right at the start of the mechanical design, since it nearly always involved some form of ducting and filtering. To check the effect of plug-in unit construction on reliability, the authors compared the figures obtained in their first years of operation from computers of conventional and plug-in unit construction, referred to as computers "A" and "B," respectively. Useful operating time with computer "A" (percentage of total operating time, including fault time, but excluding scheduled maintenance) was 96 per cent, and computer "B" 99·2 per cent. A second set of figures included the scheduled maintenance time in the denominator, which was now the total running time : computer "A" gave 69·2 per cent and computer "B" 82·1 per cent. This reflected the much greater proportion of unmaintained operating time which was possible with computer "B."

Mr. P. H. V. Maguire, E.M.I. Electronics, Ltd., said that simplicity of design was becoming the most important criterion, even at the expense of speed, and here the parallel machine offered advantages over the series. An attempt should be made in designing a machine to ensure that a fault caused the greatest possible logical damage, but only in that part of the machine in which the fault lay. The aim was to create as many symptoms as possible in the area of the fault, leaving the rest of the machine operating normally. The effects of faults should be localised by minimising the number of inputs and outputs of each discrete logical block, and all elements within a block should be utilised to maximum capacity. An example could be taken from the "Emidec 1100" machine, where simple blocks of logic were exploited to capacity by a system of "micro-programming." Complicated computer functions could thus be performed by simple logical units by controlling them in a complex manner.

Other contributors of papers to this session of the meeting were Dr. A. Kruithof, of Standard Telecommunications Laboratories, on "Statistics and Electronic Units," and Messrs. G. W. Monk and N. E. Wiseman, of Elliott Brothers (London), Ltd., on "Computer Methods Applied to the Design of Digital Circuits for Reliability."

# Large Plano-Milling Machine

*A plano-milling machine designed and built by Kendall and Gent, Ltd., for C. A. Parsons and Co., Ltd., is capable of machining components up to 35ft 6in long by 12ft wide and 9ft 6in high. This machine, weighing some 450 tons and having a bed 70ft long overall, is stated to be the largest ever built in this country, and one of the largest in the world. An impression of its size and the heavy column construction is given in the photograph taken from the rear which we reproduce on the right.*



A PLANO-MILLING machine recently completed by Kendall and Gent, Ltd., Manchester, has been specially designed for the machining of very large electrical components and steam turbine casings for the nuclear power industry at the works of C. A. Parsons and Co., Ltd., in Newcastle. With its capacity for handling work up to 35ft 6in long by 12ft wide and 9ft 6in high, this machine is one of the largest yet built. Its four milling heads are each powered by a 100 h.p. motor and are designed for use with face milling cutters up to 3ft diameter. In addition to normal milling operations the machine is arranged for " steering " control through an automobile style steering wheel at three of its operating stations. With this " steering " control the traverse motors of the table and a milling head are controlled simultaneously to guide a cutter round a complicated shape in either the vertical or the horizontal plane.

The bed of the machine is an assembly of three sections which, when bolted together, weigh 90 tons and have an overall length of 70ft. The centre bed section houses the table drive mechanism and also provides the facings for mounting the 40 h.p. table rapid traverse motor and the 25 h.p. variable d.c. feed traverse motor. A pump, which provides oil to each of the three bed slideways, is contained in the centre bed section. It supplies oil to points provided at intervals of 5ft on each slideway and the system is so designed that oil is delivered only at those points covered by the table, there being grooves in the slideways to distribute the oil to the slide faces.

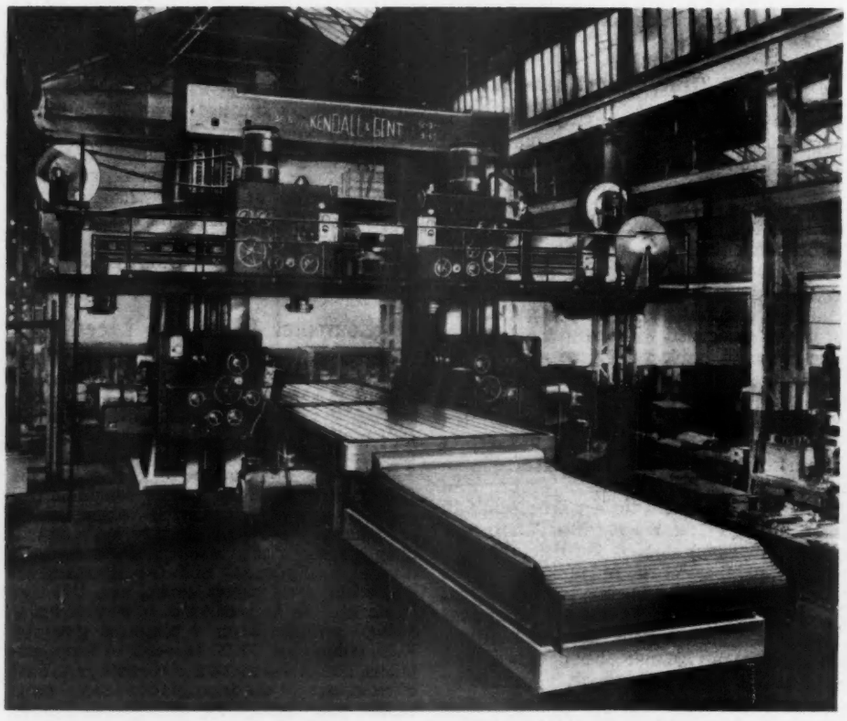
The tandem table is an assembly of four sections and is designed to carry a maximum load of 100 tons, which, with the weight of the table itself, imparts a total load of 164 tons on the bed slides. Twelve tee-slots are provided in the full length of the table together with over 200 locating holes to facilitate the setting-up of workpieces. The table is driven by the maker's worm and generated rack system in which two worms transmit drive to racks bolted on the underside of the table. The table feed rates are steplessly variable between 0 and 50in per minute by electronic control. Feed rates are selected by means of a graduated dial on each of the control desks and the precise feed selected is registered on a tachometer dial.

The two columns of the machine each weigh 43 tons and they are 24ft high with a base of 12ft by 10ft. Each column is bolted and keyed to the centre bed section and they are tied together at the top by a strong box-section cross-stay casting. In this way there is provided a square frame structure of considerable strength, well able to withstand the severest cutting forces from whichever direction they may be imposed.

The overall length of the cross slide casting is 45ft, and it weighs 40 tons. A deep section " bow " in the vertical plane extending the full length of the cross slide provides strength to the casting and eliminates the possibility of deflection when cutting. In addition to the " bow " in the vertical plane a further deep section " bow " extends across the rear of the castings between the two columns. When fully erected with the two vertical milling heads, platform, control desk and other equipment the cross slide has a total weight of 86 tons, and this weight is partially balanced by counter-weights suspended inside each of the columns.

The drive for elevating the cross slide is provided by a 45 h.p. constant speed motor which drives a 5½in diameter elevating screw housed between the slideways of each column. A compensating device is incorporated in the elevating mechanism so that, if necessary after a long period of wear, the cross slide alignment to the table can be adjusted.

Lubrication of the slide faces of the columns and also the mechanism of the elevating screws is provided by a pump mounted on the rear of the cross slide. This pump is electrically interlocked with the cross slide elevating motor and so arranged that on depressing the elevating motor start button a preset period of forced lubrication takes place before the cross slide traverse can start. When cutting, the cross slide is




**Plano-milling machine with a 37ft 6in tandem table to take work up to 12ft wide by 9ft 6in high and 100 tons in weight**

clamped to each of the columns by locking mechanisms operated remotely by two 1½ h.p. motors; electrical interlocks with the elevating motor prevent operation of the traverse until the cross slide is unlocked. Pilot lights are provided on each control station to indicate the condition of the cross slide locking mechanism.

The machine has two vertical heads on the cross slide and two horizontal heads, one on each column. Each head weighs 17 tons and is provided with its own 100 h.p. spindle drive motor. Drive is transmitted through a worm and wheel reduction unit to the spindle speed change gearbox and the final drive to the spindle is by a large diameter helical gear. Through the gearboxes there are available sixteen spindle speeds between 10 and 200 r.p.m., gear changing being effected by a handwheel. The cutter spindles are mounted in 15in diameter densified cast iron quills and run in high precision matched bearings. The quills have 22in diameter flanges to facilitate the mounting of large diameter face cutters.

A power traverse of 18in per minute is provided by individual motors to each spindle sleeve, with fine adjustment by a micrometer dial and handwheel. The combination of rapid traverse and fine feed enables accurate and rapid setting of depth of cut. Hydraulic locking is provided for clamping the spindle sleeves in position and also for locking the milling heads to their slides.

Drive for milling head feed traverse is by a 15 h.p. d.c. variable speed motor which provides infinitely variable feeds between 0 and 50in per minute. Drive for the rapid traverse of the heads is provided by a separate 20 h.p. constant speed motor and selection of feed or rapid traverse is effected by push button from the control stations. Selection of the feed required is made from a graduated dial on the control desks and the precise feed selected is registered on a tachometer dial. Large diameter handwheels equipped with micrometer dials are also provided on each milling head to facilitate fine setting adjustment. The two horizontal milling heads are partially balanced, in the same manner as the cross slide, for ease of adjustment up the column.

*Electronic Speed Control.*—Varying feed rates on the traverse drives to the table and milling heads are obtained by alteration of the driving motor speeds. As these motors have to be controlled individually during normal milling operation and also simultaneously when using the "steering" control, the adjustable speed drive equipment, supplied by Lancashire Dynamo Electronic Products, Ltd., has been designed to meet both conditions.

Control and ease of operation for both normal milling and steering means received very careful attention and the machine is provided with four control desks and two control panels which are as follows :

A master control desk situated on the floor on the right-hand side of the machine ; a travelling control desk mounted on the cross slide platform, as shown in one of our illustrations ; control desks on the right- and left-hand horizontal heads; and control panels on the right- and left-hand vertical heads. The master control desk carries controls for operation of the milling head and table rapid traverse and also the cross slide traverse. The travelling control desk and also the two desks on the horizontal milling heads carry controls for the feed and rapid traverse motions to both table and milling heads. All three of these desks are equipped with steering control handwheels. The two control panels on the vertical milling heads provide controls for rapid and feed traverse of the milling heads.

The travelling control desk on the cross slide platform is equipped with a seat for the operator and the whole unit is mounted on tracks and provided with a motor drive. This arrangement enables the operator to traverse the desk to the most convenient position for operation anywhere along the full length of the cross slide.

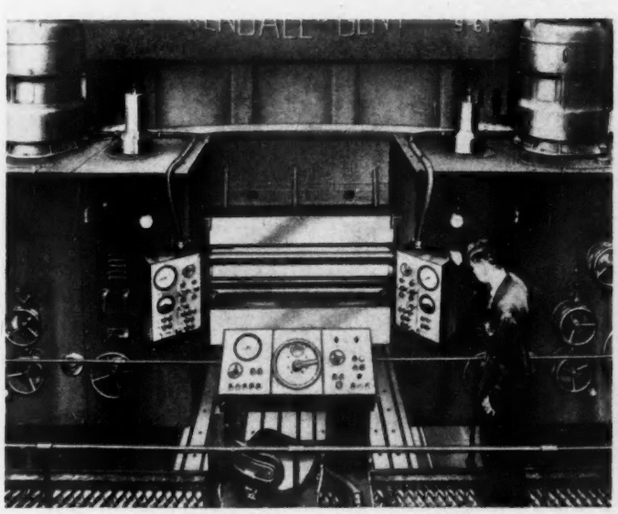
The drives for the table and milling head traverses are very similar in arrangement; each utilises a d.c. driving motor fed from its own generator, both generators being driven by a common a.c. motor in the generator set. This a.c. motor also drives an exciter generator which provides the field excitation to the two d.c. drive motors. The output voltage of the two d.c. generators, and hence the armature voltage of the table and milling head drive motors, is controlled by single-phase full-wave thyratron rectifiers feeding the generator field. The field winding of each d.c. generator is designed as a centre-tapped winding, each half-winding being controlled individually by one pair of thyratron rectifiers. This permits the two driving motors to be operated in either direction without the use of reversing contacts interposed in the armature circuit.

The directions of excitation currents through the two halves of the field winding are such that (*a*) when both halves are equally excited, the effective total field excitation for the generator is zero and the generator output is zero volts ; (*b*) when one half-winding is energised more than the other half-winding, the generator supplies d.c. voltage of a given polarity and at a magnitude proportional to the difference in excitation between the two half-windings ; and (*c*) when the latter half-winding is excited more than the former, the generator supplies d.c. voltage of the opposite polarity and at a magnitude again proportional to the difference in excitation.

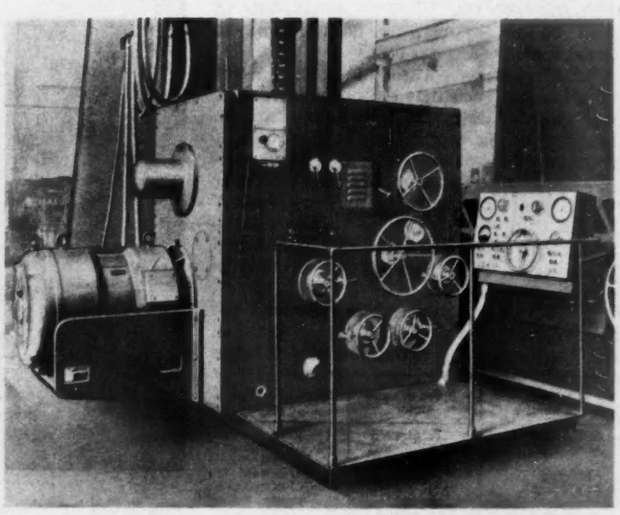
Thus by controlling the relative levels of excitation between the two halves of the field winding the output of the d.c. generator can be varied smoothly from a maximum with one polarity, through zero, to a maximum with the opposite polarity ; accordingly the speed of the driving motor can also be varied smoothly from a maximum in one direction, through zero, to a maximum in the opposite direction.

The driving motors for the table and milling head traverses are both shunt-wound, interpolar, variable speed d.c. motors, and each has an integrally mounted tachometer-generator on the non-driving end. The table feed traverse motor is rated at 25 h.p. at 510 r.p.m., and the milling head feed traverse motor is rated at 15 h.p. at 710 r.p.m.

*Normal Milling Operation.*—For normal milling operations the table traverse motor and milling head traverse motor operate under separate control systems. The tachometer-generator coupled to the driving motor generates an output d.c. voltage proportional to the speed of the motor. This output voltage is compared with a reference voltage which is controlled by the feed setting knob on the desk and an "error" signal is derived. The "error" signal is applied to the common input circuits of two amplifier channels contained in a twin channel control amplifier; the amplified voltage from each channel individually controls the excitation to each half of the generator split-field via a thyratron unit which acts as a regulator in series with the half-field winding. The amplifier circuits function in such a manner that, as the excitation to one half-winding is increased, the excitation to the other half-winding is decreased. The generator output is proportional to the difference between the



Travelling control desk on cross slide, and the vertical milling head control panels



Horizontal milling head with operator's platform and control desk

two excitations and the polarity of the output depends on which half is excited more than the other.

As the feed rate control knob on the desk is turned to increase the motor speed, the "error" signal varies in polarity and value such that the excitation to the appropriate half field is increased and that to the other half field is decreased. The converse happens when a reduction in motor speed is required.

Under steady-state conditions, i.e. with the motor operating at the speed set by the feed rate control knob, the above described control system operates such that the magnitude and polarity of the "error" signal is just sufficient to maintain the generator field excited at the level required to result in the desired motor speed. Should the motor speed vary momentarily from the set speed due to any reason (apart from re-adjustment of the feed rate control knob), for example, due to variations in load conditions, the control system quickly reacts to restore the motor speed to the set value. To ensure that the system will respond to external disturbances quickly and without tendency towards instability or to excessive overshooting, adequate stabilising feed back circuits, operative under transient conditions, are incorporated in the closed-loop control system. Other circuits are incorporated to allow pre-setting of the maximum accelerating torques and overload torques to values suitable to the equipment under control.

*Steering Control Operation.*—When the machine is operating under steering control the table and milling head traverse motors are simultaneously controlled. This allows the direction of travel of the cutter in relation to the work to be "steered" through 360 deg.,; thus the cutter can be guided round a complicated shape either in the vertical plane or horizontal plane depending upon which milling head is selected for operation. Feeds for steering are divided into two ranges, i.e. 1in to 10in per minute and 5in to 50in per minute; selection of the feed range required is made by a rotary switch on the control desks.

Feed control is by a ganged potentiometer designed to provide the correct speed from each motor to move the cutter in the direction selected by the steering handwheel. The system is so designed that only one steering handwheel can be in operation at any one time, the desk required for operation being selected from the master control desk. The control circuits for each of the two drive motors remains essentially the same as for the normal milling operation. However, the two "error" signals, one to each control system, are derived from a phase sensitive rectifier unit.

The "steering" wheel moves the motor of a magslip such that the outputs from its two data windings are proportional to the sine and cosine respectively of the angle of rotation of the wheel. The two signal outputs are applied to the phase sensitive rectifier where they are converted to two "error" signals, one to be applied to the control system governing the table feed motor and the other to the control system for the milling head feed motor.

The magslip and phase sensitive unit are so designed that the relationship between the "steeering" wheel position (shown by an indicator on the control desks ; 0 deg. at North) and the relative speeds of the two motors are as given in the table.

| Steering wheel | Speed of table motor | Speed of milling head motor |
|---|---|---|
| At 0 deg. ... ... | Max. forward | Zero |
| At 45 deg. ... ... | 0·707 of max. forward | 0·707 of max. forward |
| At 90 deg. ... ... | Zero | Max. forward |
| At 135 deg. ... ... | 0·707 of max. reverse | 0·707 of max. reverse |
| At 180 deg. ... ... | Max. reverse | Zero |

The relative motor speeds for 225 deg., 270 deg. and 315 deg. are the exact opposites of those for 45 deg., 90 deg. and 135 deg. respectively.

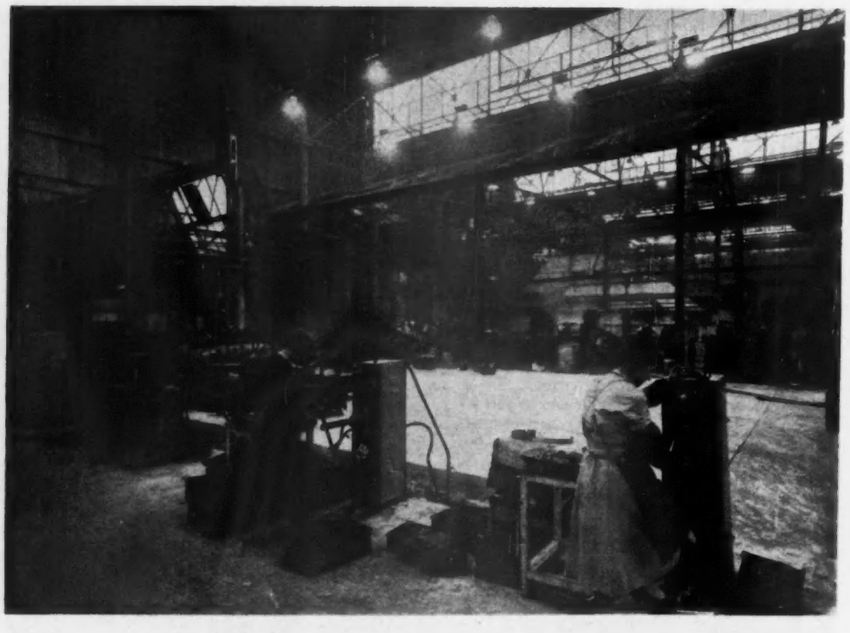
During the "steering" control, the speed of advance (i.e. the square root of the sum of the squares of the two motor speeds) is maintained constant at the value selected on the steering feed rate control knob. Thus the cutting feed of the cutter is held constant at this value irrespective of the direction of cut. The vector speed is held constant to an accuracy varying from $\pm 1$ per cent at maximum speed to $\pm 10$ per cent at minimum speed.

# Works Rebuilding and Modernisation Scheme

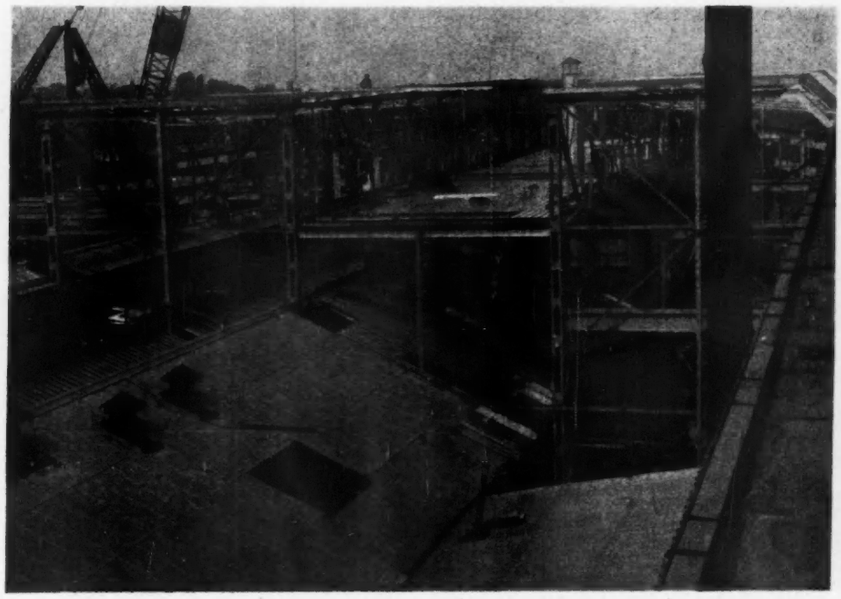
*We have received particulars of a comprehensive reconstruction and modernisation scheme which has been completed at the works of Joseph Sankey and Sons, Ltd., Bilston. This work, involving the construction of a new press shop of* 64,000 *square feet and four assembly shops and a warehouse totalling* 102,000 *square feet, was carried out without reducing the output of the works. Under the programme followed, some of the new structures were built through and around existing buildings whilst production continued uninterrupted. When the new structures were completed the old buildings they enclosed were demolished.*

UNDER a factory modernisation programme which has been carried out at a cost of £1,500,000 at the Albert Street Works, Bilston, of Joseph Sankey and Sons, Ltd., nearly four acres of the original premises have been replaced by new shops. This firm has for many years been engaged in the manufacture of a wide range of consumer goods, automobile chassis and bodies, aircraft parts, &c., many of which were made in a number of old buildings which made difficult the introduction of modern production flow methods. The work of reconstruction and reorganisation has involved the arrangement of all the original assembly shops on one level in four large parallel shops. Across one end of these shops there is a new 64,000 square foot press shop carried on a suspended floor to adapt the slope of the site to provide a basement for tool and raw materials storage and preparation. At the other end of the assembly bays there has been provided a large warehouse. A public road passing down one side of the works has been spanned by the bridge of a 250ft long conveyor by which materials and parts on pallets are taken to another section of the factory on the other side of the road.

The programme of reconstruction was carried out in stages planned to avoid any major interference with production, and much of the work itself was carried out by the work's staff. In certain cases the structures of the new buildings were erected over the existing shops, which were afterwards demolished. Production was continued in the old shops whilst the building work was in progress, and in one of our illustrations there can be seen the framework of an original building being removed from within the new one. Before the new structures were started, extensive piling had to be carried out for the main stanchion foundations. When this work had been completed, many of the main stanchions for the new shops were lowered through holes in the roofs of the older buildings and fixed on the pile caps. Another of our illustrations shows the monitor roof frame structure of one of the new shops under construction, with its



**Production being carried on in a new assembly department with old building framework being demolished over a reconstructed floor area in the background**

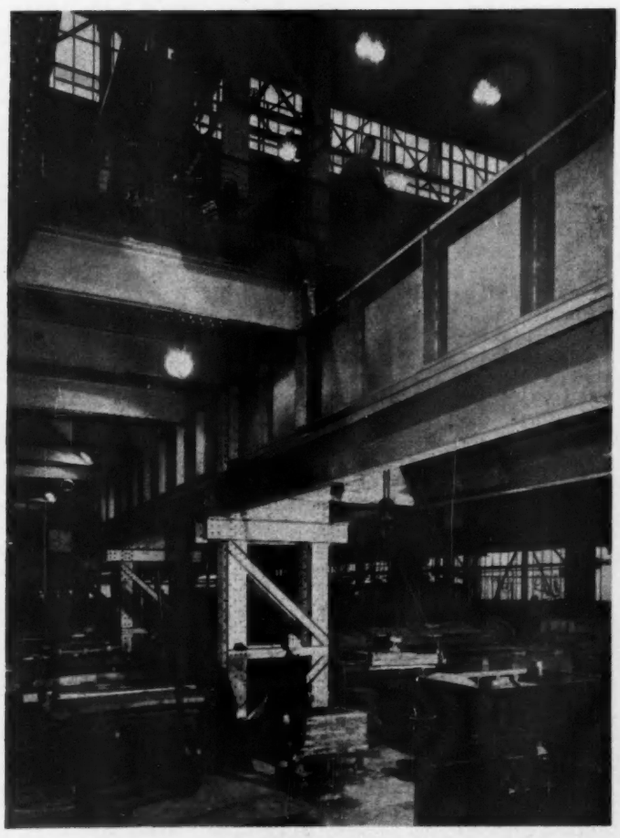


Monitor roof framework being assembled on stanchions passing through roof of an old building

stanchions passing down through the roof of the old building.

The first stage of the programme involved the erection of the new press shop on a site at one end of the works on which there were standing a galvanising and plating, a welding and a tinning department, as well as the works boiler house. The pickling and plating shops were first rehoused in premises on the other side of the road and demolition of the boiler house and adjacent buildings was started. As already mentioned, the site of this press shop slopes and it is on made-up ground over old mine workings. Preparation work for the new structure involved the driving of over a thousand piles to an average depth of 25ft, each pile being designed for a loading of 60 tons. Site clearance and excavation to provide the basement level involved the removal of nearly 100,000 cubic yards of soil, bricks and other material, and special provisions had to be made in the concrete used for the foundations owing to heavy acid and alkali contamination of the surrounding sub-soil.

The new press shop is 425ft long by 150ft wide with a height of 40ft to the underside of the monitor roof truss, and it has a 63,750 square foot basement below. The suspended floor structure of this shop can be seen in one of the illustrations. Its stanchions are arranged upon a 25ft square grid system carrying 54in deep main spine beams from which there is supported the floor beam assembly. The heavy presses are supported directly upon the beams and the floor of the shop is provided by an assembly of removable hardwood panels between the beams. This arrangement gives a high degree of plant flexibility as, when required, presses can be repositioned and the flooring easily rearranged without need for making new press foundations such as would normally be required on a ground level floor.



Materials stores and preparation section of basement. The arrangement of the main stanchions, spine beam and floor beam assembly of the suspended floor press shop can be clearly seen

Future additions to the plant or reallocation of machines to suit new forms of production will, therefore, be possible with little trouble and a minimum loss of production time. Over a hundred presses with capacities ranging from 25 to 1000 tons have been installed at present, and they are arranged in two heavy and two light lines separated by wide aisles to facilitate materials movement. Three 30-ton overhead cranes serve the shop, two over the heavy press lines and one over the lighter machine lines. The overhead conveyor to the firm's shops on the other side of the road extends from one end of the press shop.

The basement of the press shop has been divided to provide a tool stores, a tool repair section, a materials stores, a materials preparation shop and a small laboratory. Hatches in the press shop floor give direct access to the materials storage and preparation sections in the basement. By using the shop cranes to raise materials or tools straight up from the basement to the presses, a considerable amount of handling time is saved. As in all large press shops, there is a problem in handling scrap and unwieldy cut-offs during production, and in this installation it has been solved in a very simple way by providing chutes at the presses. Scrap and cut-offs from the machines gravitate down these chutes to the basement, where they fall straight into bins for transport to a baling plant in one corner without having to be transported across the press shop floor as is the procedure in most plants.

Work on the construction of the press shop started in August, 1957, and by the Easter of the following year the first machines were in operation. Reconstruction of four adjoining assembly shops and a warehouse was then started. These new buildings cover an area of 102,000 square feet and in the course of their construction two of the shops were erected over and around existing shops, as described above. The shops were rebuilt a section at a time and as work progressed plant was moved from the old lines to refloored areas in adjoining sections as they were completed. These new shops have a height of 32ft to the underside of the truss and, like the press shop, have dado walls with extensive side glazing and monitor roofs which provide a good level of natural lighting in all sections.

Under the programme of reconstruction followed, major plant moves were carried out during the night, at week-ends and during holiday periods. To reduce the effects of down-time in the plant, production runs were lengthened and increased stocks of finished products stored in temporarily rented warehouses to simplify the work of production planning in difficult periods. The effective planning and the way in which the series of building demolition and reconstruction operations were carried out, in conjunction with extensive plant and department rearrangements, was indicated by an increase of 12½ per cent in overall production during the period of the scheme.

### Pipes and Pipelines Exhibition

THE selection, fabrication, protection and correct usage of pipes and piping, hoses and tubes forms a technology which is concerned with the design of accessories as well as pipes. The industry's activities are spread over many other industries, and to bring all its ramifications under one roof and also to indicate technical progress, a Pipes and Pipelines Exhibition, sponsored by *Pipes and Pipelines*, will be held at Earls Court, London, from May 30 to June 2.

# LETTERS AND LITERATURE

## Letters to the Editor

*(We do not hold ourselves responsible for the opinions of our correspondents)*

### TEMPERATURES IN SOLAR ATMOSPHERIC ELECTRICAL DISCHARGES

SIR,—Recently (December 25 issue) I wrote in THE ENGINEER rather tentatively, or even it may have seemed almost apologetically, of a result to which my electrical discharge theory of some magnetic storms had led me, namely, that in these discharges in the solar atmosphere the temperature had probably reached the astonishingly high value of about 400,000,000 deg. K. Extenuatingly I wrote that " As temperatures of 5,000,000 deg. K. are already reached in the solar corona, and temperatures of the order of 1,000,000 deg. K. have already been attained in the laboratory, this deduction from theory need not surprise us too much." I went on to point out that there is at least one other family of cosmic electrical discharges—those in the atmospheres of the combination-spectra stars—in which the temperature likewise increases considerably —from 5000 deg. K. or 10,000 deg. K. to about 1,000,000 deg. K.—when the discharge is similarly propagated into regions of decreasing gas pressure.

Since the publication of that article I have had my attention drawn to the observations made outside the earth's atmosphere by the U.S. Navy scientists. They have observed X-rays with energies as high as 80,000 eV in solar flare studies, indicating temperatures in the solar atmosphere as high as 100,000,000 deg. Cent. So that this rather surprising deduction from my electrical discharge theory of these phenomena has not had to wait long for this equally surprising observational confirmation.

I may add that the theory was first published as a contribution to the I.E.E. Convention on Thermonuclear Processes and sent at the same time—last April—as a contribution to *Nature* where it appeared contemporaneously with the article in your journal.

C. E. R. BRUCE

Leatherhead, Surrey,
January 20, 1960.

### GAS *v.* ELECTRICITY

SIR,—Now that we are running short of suitable sites for our generating stations it occurs to me that we may one day have combined gas and electricity generating stations. Much economic benefit could be derived from this, since saving in transport, fuel, and manpower could be obtained by combining facilities for the stations.

Most gas stations are equipped with a means of electric power generation which would then be rendered unnecessary in a combined station. Incoming coal could be processed first in the gas generation station, and resulting coke could be pulverised and used as a fuel for the turbine boilers of the electricity station.

Present coal-fired electricity stations are very wasteful of the by-products which can be obtained from coal. They are also known sources of atmospheric pollution, due to the emission of large quantities of sulphur compound gases and sulphuric acid gas (arising from the fact that they use crude coal for the boilers). These by-products could be removed from the coal in the gas station prior to firing in the electricity station.

All facilities such as railway sidings, tipplers, or hopper houses could be shared in a composite station. Where fuel is seaborne then docking facilities could be shared.

Gas station thermal efficiency is rapidly approaching 90 per cent—(to the credit of all concerned). We may quite probably have, therefore, an improved all-round efficiency on the combined station since savings on the gas side would probably offset the lower thermal efficiency on the electrical side of the station.

We shall have conventional electricity generation with us for a long time to come, and society will always have a use for the by-products of gas generation, I feel then that we should by having combined stations, make far better use of the coal that we use ; indeed it will even tend to maintain the position of solid fuel as a means of electricity generation. This latter point may even delight the managers of the Coal Board !

A. C. MCMANUS

Harrow,
January 20, 1960.

## Book Reviews

**Servomechanisms and Regulating System Design. Volume I.** Second Edition. By HAROLD CHESTNUT and ROBERT W. MAYER. John Wiley and Sons, New York. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 94s.

IN general engineering practice it is only the exceptional book which stands the test of time and survives to a second edition. That this book should do so, in such a fast developing field as servomechanism design, speaks for itself and the major additions made to it since the publication of the first edition in 1955 reflect the impact of computing techniques and the development of root locus techniques for the analysis and synthesis of feedback control systems. Since its original publication it has been one of the standard text books on its subject and its universal appeal to both the student and the practising engineer probably stems from the thoroughness of its treatment which, in turn, reflects a perfect understanding in the authors backed up by a wealth of practical experience. It should be stressed that this book is written by engineers and has its origins in their experience so that the practical pitfalls and the time consuming aspect of some analytical methods are suitably stressed. Perhaps it is their practical experience of such snags which has persuaded them to invite another engineer to contribute a chapter on the fundamentals of analogue computers and so present a balanced picture of the engineering approach to the analysis and synthesis problems on servomechanisms and regulating systems.

The book begins with a descriptive chapter on the Automatic Control problem in which the factors of stability and accuracy associated with such a control are indicated. Next, the means that have been developed for solving these engineering problems are described and the general steps in solving a typical problem are outlined, stressing quite rightly, the necessity for a thorough understanding of the requirements before starting the design of a servo system. Some well balanced and informed predictions on future development of analytical methods in the control field are also included.

The second, third and fourth chapters concentrate on the usual mathematical introductions to complex numbers, differential equations and Laplace transforms. These chapters are neither better nor worse than can be found in many similar textbooks although they are somewhat more thorough.

Servo theory starts in earnest in Chapter Five with the introduction of the impedance concept which is illustrated by a series of examples. The steady-state response of a system as a function of frequency is considered in detail and the attenuation and phase angle representation of system performance for sinusoidal excitation is introduced and illustrated. The sixth chapter gives a detailed dissertation on system stability which is more illustrative than definitive. Various methods for determining system stability such as roots of characteristic equation, Routh's criterion, generalised form of Nyquist criterion and graphical determination of *locus* of roots for closed loop systems are outlined in considerable detail with particular examples of their application. This chapter has been one of the highlights of the earlier edition and has remained fundamentally unchanged.

The seventh chapter is on typical control elements and their transfer function and is included to provide a background of understanding of the kinds of problem that may be encountered in the feedback control field. The general treatment in this chapter is more qualitative than quantitative but a useful table of transfer functions derived for representative mechanical, electrical and hydraulic elements is included. The eighth chapter proceeds to a discussion on types of servomechanisms and control systems starting with a very necessary series of definitions of nomenclature before describing three common kinds of control system normally broadly referred to as displacement, rate and acceleration systems. The description of a control system in terms of its error coefficient rather than its gain constant is discussed in detail and the difference is pointed out. Standard engineering practice is, however, to refer to the gain of a system and we feel that this will, in general, continue.

When a control system contains a feed-

back loop the means for studying the effect on system performance of varying the direct or feedback transfer function are not particularly straightforward if the plot of forward transfer function is employed. Hence Chapter Nine considers the significance of the inverse plot and describes the nature of the *loci* of constant magnitude and angle. The comparative usefulness of the direct and inverse plots is, however, fully discussed. The tenth chapter introduces the design use of complex plane plots to improve system performance and introduces problems in system synthesis although these are dealt with in more detail later in the book. Problems associated with steady state performance of the controller with sinusoidal inputs are dealt with and serial networks such as phase lead and lag circuitry are considered. The limitations of such networks are pointed out, the case for feedback circuits made and various forms of such circuits discussed.

Nyquist stability criteria and complex plane diagram methods are adequate for analysis but involve much cut-and-try from the point of view of synthesis. Hence Chapter Eleven presents some of the concepts whereby the Nyquist stability criterion is interpreted in the light of Bode theorems. The mechanics of determining the attenuation and phase characteristics for the transfer functions of various kinds of control elements is presented both for approximate and exact methods of representation. Having established the general attenuation and phase angle characteristics versus frequency these methods are then used to discuss a range of typical applications, and this should prove as pleasing to the student who is concerned with learning as to the engineer who unfortunately is more concerned with application.

Chapter Thirteen is completely new to this edition and describes the root *locus* approach to analysis and synthesis. It will be noted that such methods lay stress on the time response characteristics of a system rather than the frequency response and a number of aids to drawing the root *locus* more readily are outlined.

The fourteenth chapter touches on a subject often ignored in such books, the analysis of multi-loop systems, and shows under what circumstances groups of elements can be treated in a similar fashion to single elements. Equivalent block diagram representation is outlined and a particular example of a position control system with load disturbance is discussed in detail. Perhaps the introduction of multi-loop system leads naturally to the employment of analogue computer and the fifteenth chapter by William E. Sollecito gives a good introduction to their use and is generally up to the standard of the remainder of the book. An excellent table of Transfer Impedance Functions of R-C input and output networks is included and the introduction of non-linearities into analogue set-ups discussed. It is worth noting that this is the only part of the book where significant mention of non-linear problems is made, and this again is a reflection on the state of the art of analysis of servomechanisms ; such methods are adequate when linearising assumption can be made but when significant non-linearity is involved the experimental techniques involved in analogue computing must be introduced.

In general then this book can be highly recommended for all those engaged in the servomechanism field and the second edition has undoubtedly reproduced the merits of its predecessor.

**Schwingungstechnik.** VDI-Berichte BD. 35. Lectures given at the VDI-Congress, Stuttgart, 1958. VDI-Verlag G.m.b.H., (22a), Düsseldorf 10, Prinz-Georg-Strasse 77/79. Price DM.33.20 (10 per cent rebate for VDI members).

VOLUME 35 of VDI Reports, which has now been published, contains the verbatim version of twenty lectures given at the 1958 Stuttgart Congress of the Vibrations Technology Group of the German Engineers' Association. The three main topics of the congress were : the mathematical calculations involved in the study of vibrations ; vibration problems in vehicles (rail and road vehicles, and ships) ; and technical measures for noise abatement. In the first section are dealt with the use in numerical calculations of transfer matrices, such matrices being catalogued for a large number of technically interesting cases, and the determination of eigen values with the help of transfer matrices. Another subject is that of electro-mechanical analogies as used in elementary computations.

" Active " and " passive " reduction of vibrations in ships has become of great importance, since increasing propulsive power has tended to become concentrated into single large engines and single propellers. A special design of stem allowing a free flow round the propeller has been developed by Grim which reduces interference between the hull and the propeller, as well as the natural resonant frequency of the propeller shaft, and is now being applied experimentally in two vessels of 7000 s.h.p. The use of rubber in engine supports and couplings is well known. Also described are measures taken in the construction of the German battleships to achieve a more rigid engine mounting ; another problem was the isolation from vibrations of fire-control positions. An interesting case where vibrations are artificially generated is that of a German coastal icebreaker of 1200 h.p. which enables the ship to deal with solid ice 2m thick.

Experimental investigation of hull vibrations and the measurement of hull stresses during launching are further marine topics to which papers are devoted.

In the field of road vehcies, research reports are included concerning the experimental determination of the effectiveness of shock absorbers, and practical experiences with this class of component. The influence of the mechanical properties of tyres and of the elastic and geometric properties of the bodywork, upon the riding qualities of cars, is the subject of two further papers. Rubber is widely used for the suppression of vibrations. At the congress, its behaviour was discussed from a general angle, as well as from the more specific one of its use in locomotives and railway trucks for lignite mines.

Researches concerning the effects of vibrations on the human body have been carried out at the Max-Planck Institute for Work Physiology, Dortmund. A paper read before the congress co-ordinates the results of horizontal and vertical vibrations, obtained in earlier work, with vibrations transmitted through the hands and arms.

Forced damped vibrations in systems comprising any number of masses, damping and excitation, can be calculated in a simple and clear manner by a procedure based on a method first given by Holzer. The same course can be adopted for stability investigations of feedback control loops.

Consideration of the effect of the oil film in bearings shows that under certain circumstances it has a considerable effect upon the vibration of a shaft, and, therefore, must be taken into account.

Noisiness of radial and axial blowers for mine ventilation is discussed and measures for its reduction are suggested.

Noise abatement has become one of the foremost problems affecting all branches of mechanical engineering design, but the complexity of noise spectra makes it difficult to establish simple methods of noise measurement and criteria of noisiness. Improved standards are suggested for measuring continuous and possibly also intermittent and sudden noises.

A specific problem of noise abatement is the reduction of engine noise by means of exhaust silencers. The theory of silencers is extended by introducing the Mach number of the flow, and it is shown that interference effects in the case of more than two parallel channels become negligible by comparison with other causes of damping.

**The Elements of Determinants, Matrices and Tensors for Engineers.** By S. AUSTEN STIGANT. Macdonald and Co. (Publishers), Ltd., 16, Maddox Street, London, W.1. Price 60s.

THIS book, as the title indicates, is in three parts, dealing respectively with determinants, matrices and tensors. Determinants are introduced in the conventional manner by their application to the solution of simultaneous equations. After two chapters which give very clear explanations and examples, first of second-order determinants and then of third and higher order, the mathematical principles underlying the structure of determinants and their defining properties are given. This leads to two chapters, entitled " Manipulation," which cover comprehensively determinant operations, such as the processes of addition, subtraction and multiplication and methods of reduction.

A similar procedure and sequence are followed in Part II, matrices. Simultaneous equations again form the introduction. There are corresponding chapters which explain and illustrate second, third and higher order matrices ; give the mathematical structure of matrix operators and their defining properties ; and, under the heading manipulation, cover the processes of transposition, addition and subtraction, kinds of multiplication, partitioning, diagonalisation and inversion.

Part III, " Tensors," which occupies about half of the book, starts with a chapter giving introductory ideas. In the subsequent chapters the following subjects are covered : reference frames and axes, index and direct notations, variance and association, transformation, the Kronecker delta, actual and primitive networks. From the beginning the electrical quantities of voltage, current and impedance are used to illustrate the formation of the tensor equations and their manipulations. The last chapter in this part gives the solutions by means of tensors of a number of electrical networks. There are four appendices which carry the treatment beyond the standard of the main text.

Great care has been taken in all the parts of the book to present the subject matter clearly and simply, and every detailed step is given in the mathematical workings. The explanation is helped by a large number of worked examples. The clarity is further enhanced by the high standard achieved in the production of the book. The mathematical symbols, such as enclosures, the extensive equations, and the different kinds of indices needed for these subjects, are very clearly presented, as also are the diagrams and tables. The author has achieved his stated object of presenting an elementary conception of his chosen subjects. He has

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Present coal-fired electricity stations are very wasteful of the by-products which can be obtained from coal. They are also known sources of atmospheric pollution, due to the emission of large quantities of sulphur compound gases and sulphuric acid gas (arising from the fact that they use crude coal for the boilers). These by-products could be removed from the coal in the gas station prior to firing in the electricity station.

All facilities such as railway sidings, tipplers, or hopper houses could be shared in a composite station. Where fuel is seaborne then docking facilities could be shared.

Gas station thermal efficiency is rapidly approaching 90 per cent—(to the credit of all concerned). We may quite probably have, therefore, an improved all-round efficiency on the combined station since savings on the gas side would probably offset the lower thermal efficiency on the electrical side of the station.

We shall have conventional electricity generation with us for a long time to come, and society will always have a use for the by-products of gas generation, I feel then that we should by having combined stations, make far better use of the coal that we use ; indeed it will even tend to maintain the position of solid fuel as a means of electricity generation. This latter point may even delight the managers of the Coal Board !

A. C. MCMANUS

Harrow,
January 20, 1960.

## Book Reviews

**Servomechanisms and Regulating System Design. Volume I.** Second Edition. By HAROLD CHESTNUT and ROBERT W. MAYER. John Wiley and Sons, New York. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 94s.

IN general engineering practice it is only the exceptional book which stands the test of time and survives to a second edition. That this book should do so, in such a fast developing field as servomechanism design, speaks for itself and the major additions made to it since the publication of the first edition in 1955 reflect the impact of computing techniques and the development of root locus techniques for the analysis and synthesis of feedback control systems. Since its original publication it has been one of the standard text books on its subject and its universal appeal to both the student and the practising engineer probably stems from the thoroughness of its treatment which, in turn, reflects a perfect understanding in the authors backed up by a wealth of practical experience. It should be stressed that this book is written by engineers and has its origins in their experience so that the practical pitfalls and the time consuming aspect of some analytical methods are suitably stressed. Perhaps it is their practical experience of such snags which has persuaded them to invite another engineer to contribute a chapter on the fundamentals of analogue computers and so present a balanced picture of the engineering approach to the analysis and synthesis problems on servomechanisms and regulating systems.

The book begins with a descriptive chapter on the Automatic Control problem in which the factors of stability and accuracy associated with such a control are indicated. Next, the means that have been developed for solving these engineering problems are described and the general steps in solving a typical problem are outlined, stressing quite rightly, the necessity for a thorough understanding of the requirements before starting the design of a servo system. Some well balanced and informed predictions on future development of analytical methods in the control field are also included.

The second, third and fourth chapters concentrate on the usual mathematical introductions to complex numbers, differential equations and Laplace transforms. These chapters are neither better nor worse than can be found in many similar textbooks although they are somewhat more thorough.

Servo theory starts in earnest in Chapter Five with the introduction of the impedance concept which is illustrated by a series of examples. The steady-state response of a system as a function of frequency is considered in detail and the attenuation and phase angle representation of system performance for sinusoidal excitation is introduced and illustrated. The sixth chapter gives a detailed dissertation on system stability which is more illustrative than definitive. Various methods for determining system stability such as roots of characteristic equation, Routh's criterion, generalised form of Nyquist criterion and graphical determination of *locus* of roots for closed loop systems are outlined in considerable detail with particular examples of their application. This chapter has been one of the highlights of the earlier edition and has remained fundamentally unchanged.

The seventh chapter is on typical control elements and their transfer function and is included to provide a background of understanding of the kinds of problem that may be encountered in the feedback control field. The general treatment in this chapter is more qualitative than quantitative but a useful table of transfer functions derived for representative mechanical, electrical and hydraulic elements is included. The eighth chapter proceeds to a discussion on types of servomechanisms and control systems starting with a very necessary series of definitions of nomenclature before describing three common kinds of control system normally broadly referred to as displacement, rate and acceleration systems. The description of a control system in terms of its error coefficient rather than its gain constant is discussed in detail and the difference is pointed out. Standard engineering practice is, however, to refer to the gain of a system and we feel that this will, in general, continue.

When a control system contains a feed-

back loop the means for studying the effect on system performance of varying the direct or feedback transfer function are not particularly straightforward if the plot of forward transfer function is employed. Hence Chapter Nine considers the significance of the inverse plot and describes the nature of the *loci* of constant magnitude and angle. The comparative usefulness of the direct and inverse plots is, however, fully discussed. The tenth chapter introduces the design use of complex plane plots to improve system performance and introduces problems in system synthesis although these are dealt with in more detail later in the book. Problems associated with steady state performance of the controller with sinusoidal inputs are dealt with and serial networks such as phase lead and lag circuitry are considered. The limitations of such networks are pointed out, the case for feedback circuits made and various forms of such circuits discussed.

Nyquist stability criteria and complex plane diagram methods are adequate for analysis but involve much cut-and-try from the point of view of synthesis. Hence Chapter Eleven presents some of the concepts whereby the Nyquist stability criterion is interpreted in the light of Bode theorems. The mechanics of determining the attenuation and phase characteristics for the transfer functions of various kinds of control elements is presented both for approximate and exact methods of representation. Having established the general attenuation and phase angle characteristics versus frequency these methods are then used to discuss a range of typical applications, and this should prove as pleasing to the student who is concerned with learning as to the engineer who unfortunately is more concerned with application.

Chapter Thirteen is completely new to this edition and describes the root *locus* approach to analysis and synthesis. It will be noted that such methods lay stress on the time response characteristics of a system rather than the frequency response and a number of aids to drawing the root *locus* more readily are outlined.

The fourteenth chapter touches on a subject often ignored in such books, the analysis of multi-loop systems, and shows under what circumstances groups of elements can be treated in a similar fashion to single elements. Equivalent block diagram representation is outlined and a particular example of a position control system with load disturbance is discussed in detail. Perhaps the introduction of multi-loop system leads naturally to the employment of analogue computer and the fifteenth chapter by William E. Sollecito gives a good introduction to their use and is generally up to the standard of the remainder of the book. An excellent table of Transfer Impedance Functions of R-C input and output networks is included and the introduction of non-linearities into analogue set-ups discussed. It is worth noting that this is the only part of the book where significant mention of non-linear problems is made, and this again is a reflection on the state of the art of analysis of servomechanisms ; such methods are adequate when linearising assumption can be made but when significant non-linearity is involved the experimental techniques involved in analogue computing must be introduced.

In general then this book can be highly recommended for all those engaged in the servomechanism field and the second edition has undoubtedly reproduced the merits of its predecessor.

**Schwingungstechnik.** VDI-Berichte BD. 35. Lectures given at the VDI-Congress, Stuttgart, 1958. VDI-Verlag G.m.b.H., (22a), Düsseldorf 10, Prinz-Georg-Strasse 77/79. Price DM.33.20 (10 per cent rebate for VDI members).

VOLUME 35 of VDI Reports, which has now been published, contains the verbatim version of twenty lectures given at the 1958 Stuttgart Congress of the Vibrations Technology Group of the German Engineers' Association. The three main topics of the congress were : the mathematical calculations involved in the study of vibrations ; vibration problems in vehicles (rail and road vehicles, and ships) ; and technical measures for noise abatement. In the first section are dealt with the use in numerical calculations of transfer matrices, such matrices being catalogued for a large number of technically interesting cases, and the determination of eigen values with the help of transfer matrices. Another subject is that of electro-mechanical analogies as used in elementary computations.

" Active " and " passive " reduction of vibrations in ships has become of great importance, since increasing propulsive power has tended to become concentrated into single large engines and single propellers. A special design of stem allowing a free flow round the propeller has been developed by Grim which reduces interference between the hull and the propeller, as well as the natural resonant frequency of the propeller shaft, and is now being applied experimentally in two vessels of 7000 s.h.p. The use of rubber in engine supports and couplings is well known. Also described are measures taken in the construction of the German battleships to achieve a more rigid engine mounting ; another problem was the isolation from vibrations of fire-control positions. An interesting case where vibrations are artificially generated is that of a German coastal icebreaker of 1200 h.p. which enables the ship to deal with solid ice 2m thick.

Experimental investigation of hull vibrations and the measurement of hull stresses during launching are further marine topics to which papers are devoted.

In the field of road vehcies, research reports are included concerning the experimental determination of the effectiveness of shock absorbers, and practical experiences with this class of component. The influence of the mechanical properties of tyres and of the elastic and geometric properties of the bodywork, upon the riding qualities of cars, is the subject of two further papers. Rubber is widely used for the suppression of vibrations. At the congress, its behaviour was discussed from a general angle, as well as from the more specific one of its use in locomotives and railway trucks for lignite mines.

Researches concerning the effects of vibrations on the human body have been carried out at the Max-Planck Institute for Work Physiology, Dortmund. A paper read before the congress co-ordinates the results of horizontal and vertical vibrations, obtained in earlier work, with vibrations transmitted through the hands and arms.

Forced damped vibrations in systems comprising any number of masses, damping and excitation, can be calculated in a simple and clear manner by a procedure based on a method first given by Holzer. The same course can be adopted for stability investigations of feedback control loops.

Consideration of the effect of the oil film in bearings shows that under certain circumstances it has a considerable effect upon the vibration of a shaft, and, therefore, must be taken into account.

Noisiness of radial and axial blowers for mine ventilation is discussed and measures for its reduction are suggested.

Noise abatement has become one of the foremost problems affecting all branches of mechanical engineering design, but the complexity of noise spectra makes it difficult to establish simple methods of noise measurement and criteria of noisiness. Improved standards are suggested for measuring continuous and possibly also intermittent and sudden noises.

A specific problem of noise abatement is the reduction of engine noise by means of exhaust silencers. The theory of silencers is extended by introducing the Mach number of the flow, and it is shown that interference effects in the case of more than two parallel channels become negligible by comparison with other causes of damping.

**The Elements of Determinants, Matrices and Tensors for Engineers.** By S. AUSTEN STIGANT. Macdonald and Co. (Publishers), Ltd., 16, Maddox Street, London, W.1. Price 60s.

THIS book, as the title indicates, is in three parts, dealing respectively with determinants, matrices and tensors. Determinants are introduced in the conventional manner by their application to the solution of simultaneous equations. After two chapters which give very clear explanations and examples, first of second-order determinants and then of third and higher order, the mathematical principles underlying the structure of determinants and their defining properties are given. This leads to two chapters, entitled " Manipulation," which cover comprehensively determinant operations, such as the processes of addition, subtraction and multiplication and methods of reduction.

A similar procedure and sequence are followed in Part II, matrices. Simultaneous equations again form the introduction. There are corresponding chapters which explain and illustrate second, third and higher order matrices ; give the mathematical structure of matrix operators and their defining properties ; and, under the heading manipulation, cover the processes of transposition, addition and subtraction, kinds of multiplication, partitioning, diagonalisation and inversion.

Part III, " Tensors," which occupies about half of the book, starts with a chapter giving introductory ideas. In the subsequent chapters the following subjects are covered : reference frames and axes, index and direct notations, variance and association, transformation, the Kronecker delta, actual and primitive networks. From the beginning the electrical quantities of voltage, current and impedance are used to illustrate the formation of the tensor equations and their manipulations. The last chapter in this part gives the solutions by means of tensors of a number of electrical networks. There are four appendices which carry the treatment beyond the standard of the main text.

Great care has been taken in all the parts of the book to present the subject matter clearly and simply, and every detailed step is given in the mathematical workings. The explanation is helped by a large number of worked examples. The clarity is further enhanced by the high standard achieved in the production of the book. The mathematical symbols, such as enclosures, the extensive equations, and the different kinds of indices needed for these subjects, are very clearly presented, as also are the diagrams and tables. The author has achieved his stated object of presenting an elementary conception of his chosen subjects. He has

# LETTERS AND LITERATURE *(Continued)*

catered for the reader who wishes to start at the beginning, is not concerned with the formal aspects of the mathematics, and wants to use these mathematical tools for the solution of practical engineering problems. There will be many who, despite the author's encouragement, feel they have no need to acquire a working knowledge of all the mathematical methods that are given in this book. Tensors are at present outside the syllabus of most examinations ; the engineer can solve all his network problems without recourse to tensor transformations. However, the first two parts of the book, determinants and matrices, are of general value, particularly to the student. For those parts alone, as well as for the whole for those who are persuaded, the book is recommended.

**Das Walzen von Hohlkörpern und Kalibrieren von Werkzeugen zur Herstellung Nahtloser Rohre.** By PAUL GRUNER. Springer - Verlag, Berlin - Wilmersdorf, Heidelberger Platz 3. Price, DM.52.50.

BECAUSE of their great strength and inherent lightness, tubular elements, in particular those employing seamless tubes, have found an ever-increasing field of application in recent years, ranging from the traditional bicycle and motor-cycle frames, multi-wheeled road vehicles and aircraft to scaffolding and cradles as well as large and intricate permanent structures such as roofs and lattice masts. In addition to these newer applications, the use of tubes as conduits of liquids and gases has also increased to a substantial degree. These developments were made possible largely by improved methods of seamless tube production by rolling which are comprehensively reviewed in the present book. Beginning with a survey of general roll pass design, the author discusses the principal rolling faults and the design of drawing dies and pilzer rolls. These chapters are followed by the main sections which are concerned with the production of tubes of large diameter by radial rolling methods and the various skew rolling processes for making seamless tubes from solid billets. The physical principles of reducing rolling, skew rolling and levelling are discussed in detail, and a final mathematical section gives the derivation of the stress formulæ which occur.

**Resolution par analogie électrique d'équations aux deriveés partielles du quatrième ordre intervenant dans divers problèmes d'élasticité.** By JEAN BOSCHER. Publications Scientifiques et Techniques du Ministère de l'Air, No. 348. Service de Documentation et d'Information Technique de l'Aéronautique, Magasin C.T.O., 2, Avenue de la Porte-d'Issy, Paris (15e). Price Fr.2250.

IN the theory of elasticity partial differential equations of the fourth order (biharmonic functions) occur in many problems. Here an electrical analog method is described by which they may be solved. Numerous examples are given with the object of showing the manner of carrying out actual investigations. Comparison with calculation shows that errors are of the order 0·01 to 0·001. Even in cases where such accuracy is considered insufficient, the method may be found suitable in preliminary work, pending more exact numerical calculation.

## Books of Reference

*Produktenboek V.M.I.* 1958.—Published by the Netherlands Association of Metalworking Industries, Vereniging Van Metaal- Industrieën, 13, Nassaulaan, The Hague. Free on application.—The present second edition of the handbook of the Association of Metalworking Industries, to which belong more than 70 per cent of the Dutch firms in this field, contains an alphabetic index of manufacturers, a product index arranged in subject groups in Dutch, English, French and Spanish, as well as separate alphabetic subject indexes in those languages.

*Seibt Export Directory of German Industries.*—Edited by A. Seibt. Seibt-Verlag Dr. Artur Seibt, Lengdorf (Isen), Obb, and Munich 2. Obtainable in the United Kingdom from the Representative, M. Neven du Mont, 123, Pall Mall, London, S.W.1. Price £3 5s.—The fourteenth edition of the *Seibt Export Directory of German Industries*, formerly the official Handbook of the Federation of German Industries, has now been published. The main body of the handbook comprises a classified list of suppliers arranged according to the 150 branches of the German industries' classification, together with a section on exports, imports, foreign trade banks, and advertisements. A list of firms' addresses arranged under place of domicile and an index to trade marks add to the usefulness of the directory.

*Plastic Properties of Rolled Sections.* British Welding Research Association, 29, Park Crescent, London, W.1. Price 8s. 6d.—This work of reference on the plastic moduli of steel joists, beams and channels was compiled by Dr. M. R. Horne in the course of work being carried out on the plastic theory of structures at Cambridge. It deals comprehensively with the plastic moduli, with and without load, of British Standard rolled steel joists, British broad flange beams, universal beam sections, British Standard channels and special channels. A further section is devoted to the properties of British Standard equal and unequal angles. The various tables are fully explained ; they are in part extracted from B.S. 4 : 1932. Algebraic expressions for the various properties quoted, with details of their derivation, are given in three appendices. Advice on the content and form of the work was given by the D.1 (Load Carrying Capacity of Frame Structures) committee of the British Welding Research Association, and new information, given by The Bethlehem Steel Company, U.S.A., The South Durham Steel and Iron Company and Dorman Long and Co., Ltd., is also included.

## Books Received

*Mechanisms and Motion.* By K. H. Hunt. The English Universities Press, Ltd., 102, Newgate Street, London, E.C.1. Price 21s.

*Impulse-Voltage Testing.* Vol. XV. By W. G. Hawley. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 32s.

*Sam Dykes—Marine Engineer.* By D. G. Alcock. Chatto and Windus, Ltd., 40-42, William IV Street, London, W.C.2. Price 8s. 6d.

*The Operation of Sterilising Autoclaves.* The Pharmaceutical Press, 17, Bloomsbury Square, London, W.C.1. Price 7s. 6d.

*Advanced Structural Design.* By C. S. Benson. B. T. Batsford, Ltd., 4, Fitzhardinge Street, Portman Square, London, W.1. Price 50s.

*Das Waagerecht-Bohr-und Fräswerk und seine Anwendung.* By H. Schallbroch, Springer-Verlag, Berlin-Wilmersdorf, Heidelberger Platz 3, W. Germany. Price DM.26.70.

*Examples of the Design of Reinforced Concrete Buildings.* Second Edition. By Charles E. Reynolds. Concrete Publications, Ltd., 14, Dartmouth Street, London, S.W.1. Price 12s. 6d.

*The Performance of Lubricating Oils.* Second Edition. By H. H. Zuidema. Reinhold Publishing Corporation, New York, Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 56s.

## British Standards Institution

*All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.*

### CORROSION-INHIBITED ETHANEDIOL FOR WATER-COOLED ENGINES

Nos. 3150, 3151 and 3152. Price, 3150 and 3151, 4s. 6d. each ; 3152, 4s. The committee of experts responsible for these new publications studied the possibility of preparing one specification for anti-freeze suitable for all types of engine ; but it was found that this was not possible. The three standards cover formulations which have been proved in use. Not all the compositions will be equally suitable for every type of engine, owing to the different metals, dimensions and temperatures found in different classes and makes of engine. The user is therefore counselled to seek the advice of the engine manufacturer regarding which of the three types of anti-freeze are suitable for his particular engine.

B.S.3150 covers ethanediol (" ethylene glycol ") inhibited with triethanolammonium orthophosphate and sodium mercaptobenzothiazole. This formulation is one which was developed for use in aircraft piston engines; it has already become well known as the subject of Ministry of Supply specification D.T.D. 779.

B.S.3151 covers ethanediol inhibited with sodium benzoate and sodium nitrite. This formulation is based on work carried out by the Chemical Research Laboratory (now the National Chemical Laboratory) of the D.S.I.R.

B.S.3152 covers ethanediol inhibited with sodium tetraborate (" borax ") and is a formulation widely used in the U.S.A.

### THE SAMPLING AND ANALYSIS OF FUEL GAS

No. 3156 : 1959. Price 25s. This publication is arranged in three main sections dealing with fuel gas, sampling, general analysis, and special determinations. Methods are specified for obtaining snap samples, samples collected over a period under steady conditions, and samples collected over a period under fluctuating conditions. The three types of apparatus for general analysis described and illustrated include the constant-volume apparatus, the soap-film apparatus, and the " Metro " apparatus for nitrogen. Special determinations comprise those dealing with sulphur compounds, condensable vapours, nitrogenous gum, tar fog, ammonia, naphthalene, water vapour, hydrogen cyanide, iron carbonyl, specific gravity and miscellaneous properties. The determination of calorific value which is briefly discussed will later form the subject of a separate British Standard.

The methods of analyses are based mainly on information supplied by the British Coal Utilisation Research Association, British Coke Research Association, the former D.S.I.R. Fuel Research Station, North Thames Gas Board and South Eastern Gas Board. The publication does not deal with methods of analysis based on spectroscopy, interferometry, chromatography and similar techniques which will be the subject of other standards, if or when their state of development and sphere of application justify standardisation.

### CHARPY V-NOTCH IMPACT TEST

No. 131. Part 2: 1959. Price 4s. This part of the standard specifies the conditions for carrying out the Charpy V-notch impact test. It gives dimensions of test pieces with appropriate machining tolerances, the tolerances for ferrous test pieces being in accordance with a recommendation of the International Standards Organisation, whilst for non-ferrous materials a more restrictive tolerance has been applied.

Three new subsidiary test pieces have been specified to replace the two specified in the previous edition and these are intended for use when it is impossible to obtain a standard test piece from the material available. Two of the sizes selected meet the particular requirements of manufacturers of tubes. The structural and dimensional aspects of the testing machine are fully dealt with ; and an appendix gives recommendations for its installation.

### LOADED AND UNLOADED EBONITE FOR GENERAL PURPOSES

No. 3164 : 1959. Price 3s. This publication is complementary to the standard for ebonite for electrical purposes (B.S. 234), and it specifies three types of material for supply in sheet, rod, tube, or moulding form. Among the other requirements in the specification are those relating to plastics yield and cross-breaking strength, finish and machining.

THE ENGINEER

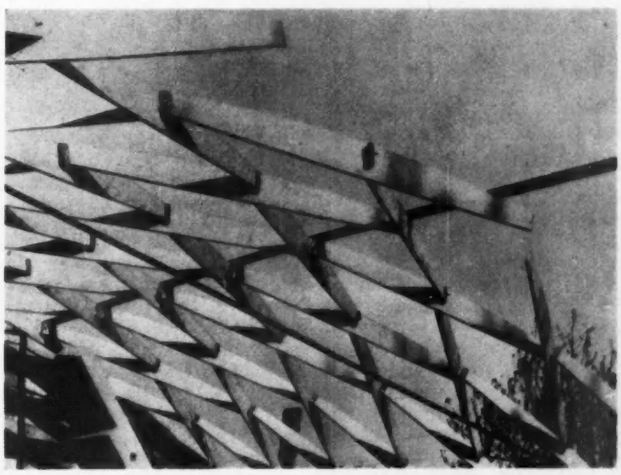
Technical Contributors Section

JANUARY 1960

# The Lamella Roof

By D. SMOLLETT, B.Sc.(Eng.), A.M.I.C.E., D.I.C.*

*The lamella roof is briefly described, and the classical, though approximate, method used to analyse it is explained. A rigorous analysis was undertaken by the author at Imperial College. This method is explained, an example of its use is given, and the results of rigorous and approximate analyses are compared. An experimental determination of the influence of gable ends is also described. A timber lamella roof is shown under construction on the right.*†



THE classical lamella roof is a barrel-vault; the section being a circular, elliptical, two-centred or other arch. The structure is supported at the arch springings along its entire length and the ends are closed either by hipping or by a rigid diaphragm. Other, more complicated, structures have been built by the lamella system, but will not be considered in this article.

Historically, the roof derives from the "planked arch" favoured by eighteenth and nineteenth century architects in which parallel arches formed the barrel-vault ribs. Each arch was built up from two layers of short, shaped timber planks, one layer lapping the joints of the other. Thus, the strength of the arch—assuming the connection between the two layers to be effective—was that of the section of a single plank. Purlins then spanned between the arches and carried the roofing.

Early in the twentieth century a German engineer, Zollinger, of Merseburg, improved on this by incorporating arches and purlins in one integral structure, the lamella roof. The two layers of the planked arch were separated and splayed and arranged so as to connect with the neighbouring arch, similarly separated, thus covering the entire building area with a lozenge-shaped pattern of interconnecting units, rather like a diagrid curved to the barrel-vault shape. The roofing material can then be applied directly to the lamella units. This may be in the form of timber boarding—or, as in a recent case, sheets of plywood—and then the structure assumes the appearance and some of the properties of a shell roof.

The commonly used method of analysis is due in the first instance to Professor Otzen, of Hannover, and his work can be found in Gesteschi's *Der Holzbau*. Crestin, in *Genie Civil*, makes use of it, and there is a reference in English in *Wood* of July/August, 1956.

The analysis is basically the same as would be employed for the planked arch described above. Thus, depending on the end conditions at the springings, a two-pinned or encastré arch of the given shape is subjected to the given loads and analysed by the standard method and the stresses due to the direct forces and moments found. As in the case of the planked arch, both layers are considered to take direct compression, but only one layer can be utilised in bending. Allowance is made for the inclination of the lamella members (as against the planked arch) by inserting a factor of $1/(\cos \alpha/2)$.

The above authors admit that the method is approximate only, but hold that rigorous analysis is difficult if not impossible due to the number of redundancies in the actual structure. With the present state of knowledge of structural analysis and especially in view of the help obtainable from the use of electronic computers, the present author undertook the rigorous analysis of a typical lamella roof. The method adopted was to consider the consequences of displacing any one of the nodes formed by the intersection of the lamella members in producing direct and bending forces at the displaced and adjacent nodes, and thus obtain "influence factors" for unit displacements.

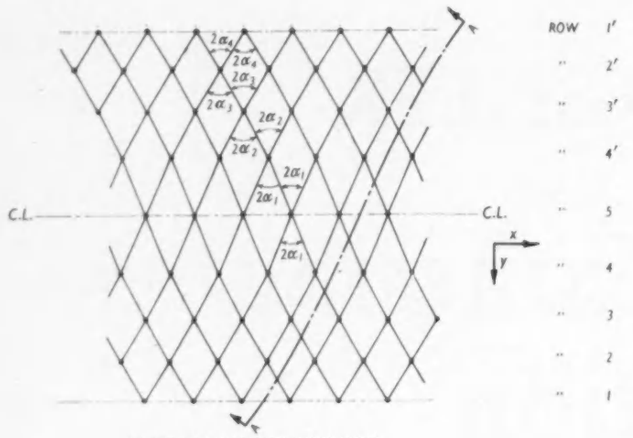
The actual lamella roof considered had nine rows of nodes, the two lowest lying on the continuously supported wall plates at the springings of the vault, as shown in Fig. 1.

The following was postulated: (1) the lamella roof is a "long roof," i.e. the effect of gable stiffening can be ignored; (2) the type of loading is linear, i.e. all nodes lying on the same horizontal line are equally loaded and thus equally displaced.

All nodes are thus free to rotate in the plane of section normal to the length of the roof and none of them will rotate in the other planes by reason of the above.

* Partner, Messrs. Smollett and Magasiner, consulting engineers.

† The analysis undertaken presupposes a perfectly rigid joint at all the intersections, as for *in-situ* concrete connections, welded steel or some types of similar roof. The heading illustration shows a *timber-lamella with bolted connections* when a different set of stiffness matrix coefficients would apply. The principle, however, is identical, and the matrices have been calculated by the author. The results are comparable, bending moments in individual units being approximately doubled as only one lamella acts in bending at each intersection. Deflections are, of course, much greater.




SCHEMATIC PART PLAN OF LAMELLA ROOF.

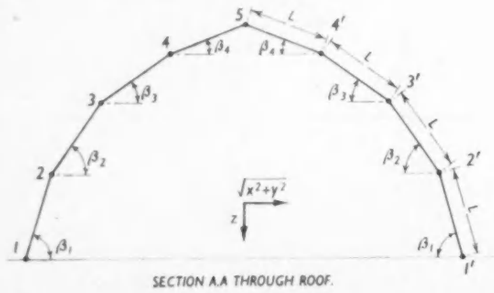
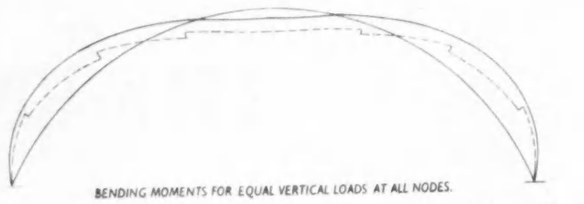
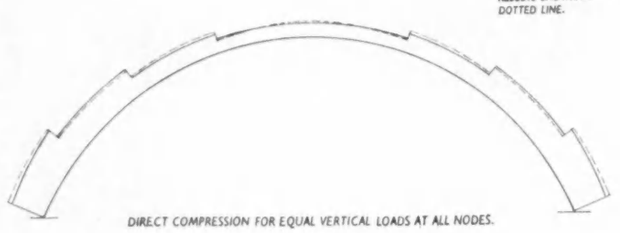



**Fig. 1—Basic plan and section of roof showing angles referred to symbolically in the matrix equations**



BENDING MOMENTS FOR EQUAL VERTICAL LOADS AT ALL NODES.

RIGOROUS ANALYSIS RESULTS SHOWN BY DOTTED LINE.



DIRECT COMPRESSION FOR EQUAL VERTICAL LOADS AT ALL NODES.

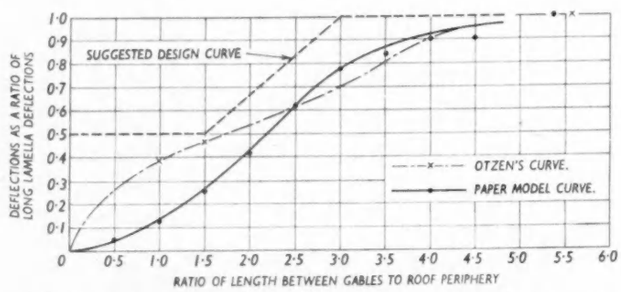

SUGGESTED DESIGN CURVE
OTZEN'S CURVE.
PAPER MODEL CURVE.
DEFLECTIONS AS A RATIO OF LONG LAMELLA DEFLECTIONS
RATIO OF LENGTH BETWEEN GABLES TO ROOF PERIPHERY

**Fig. 2—Gable-end graph and graphical comparison of results obtained by rigorous and approximate analyses of long lamella**

Similarly, none of the nodes will move along the length of the structure. The nodes 1 and 1′ at the springings are fixed in position and cannot move at all but merely rotate.

Arising from this, the number of degrees of freedom of the structure can be seen to be $(7\times3)$ plus $(2\times1)=23$.

Most roofs are symmetrical and this produces a simplification for under a symmetrical loading a symmetrical structure will deform symmetrically. Under an antimetrical (mirror-image) loading, a symmetrical structure will deform antimetrically.

Any loading can be split up into the sum of a symmetrical and an antimetrical loading. If this is done here we obtain two sets of eleven and twelve simultaneous equations respectively instead of one set of twenty-three.

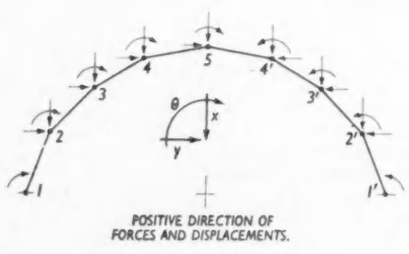
Each of these simultaneous equations expresses one of the external forces or moments acting at a node in terms of the movements and rotations of all the nodes. The solution of the equations gives the complete deformed picture of the structure under the system of forces acting. Knowing the deformed picture, the actual stresses in the members can be calculated.

The construction of the equations is wearisome ; it is, however, a task which is basically simple and depends solely on the application of the principles of statics. Unceasing attention, especially to signs, is, however, required. Once this task has been carried out, for say a nine-node lamella roof, as in the present case, all other conformations of nine-node lamella roofs have been covered, and the system is easily adaptable for other types. Thus, a book of tables, similar to Kleinlogel's, will absolve the designer from these labours.

These equations were solved—not by the impossibly laborious methods of classical algebra, but by matrix inversion. This technique leads to a solution in general terms so that once a set of coefficients characteristic for a structure has been calculated, a general solution is found and the deformed picture of the structure for any system of loads can be obtained without repeating the calculations. The process of

| | |
|---|---|
| Lamella section ... ... ... ... | $A=b\times d$ |
| Lamella length ... ... ... ... | $L$ |
| Maximum inertia ... ... ... ... | $I_1=bd^3/12$ |
| Minimum inertia ... ... ... ... | $I_2=b^3d/12$ |
| Polar inertia ... ... ... ... | $I_p=I_1+I_2$ |
| Modified $I_p$ [St. Venant] ... ... ... | $J=A^4/4\pi^2I_p$ |
| Young's modulus ... ... ... ... | $E$ |
| Poissons ratio ... ... ... ... | $\mu$ |
| Shear modulus ... ... ... ... | $C$ |

Physical properties of lamella unit




POSITIVE DIRECTION OF FORCES AND DISPLACEMENTS.

| | |
|---|---|
| $2\times[AE/L-12EI_1/L^3]$ ... ... | A |
| $2\times AE/L$ ... ... ... ... | B |
| $2\times12EI_1/L^3$ ... ... ... | C |
| $2\times12\ EI_2/L^3$ ... ... ... | D |
| $2\times6EI_1/L^2$ ... ... ... | E |
| $2\times6EI_2/L^2$ ... ... ... | F |
| $2\times2\ EI_1/L$ ... ... ... ... | G |
| $2\times CJ/L$ ... ... ... ... | H |
| $2\times4EI_1/L$ ... ... ... ... | J |
| $2\times4EI_2/L$ ... ... ... ... | K |
| $2\times2EI_2/L$ ... ... ... ... | L |

Physical constants derived from physical properties and used in matrix

| Function → / Position of unit ↓ | $\alpha$ | $\beta$ | Sin $\alpha$ | Sin $\beta$ | Cos $\alpha$ | Cos $\beta$ | Ccs $\alpha$ Cos $\beta$ Sin $\beta$ | Cos$^2\alpha$ Cos$^2\beta$ | Cos$^2\alpha$ Sin$^2\beta$ | Sin$^2\alpha$ | Cos$^2\alpha$ | Cos$^2\beta$ | Sin$^2\beta$ | Cos $\beta$ Cos $\alpha$ | Sin$\beta$ Cos$^2\alpha$ | Sin $\beta$ Sin$^2\alpha$ | Sin$^2\alpha$ Cos$^2\beta$ | Sin$^2\alpha$ Sin$^2\beta$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1–2 Suffix 1 | $\alpha_1$ | $\beta_1$ | $\rho_1$ | $\sigma_1$ | $\tau_1$ | $\chi_1$ | $\gamma_1$ | $\delta_1$ | $\gamma_1$ | $\xi_1$ | $\varepsilon_1$ | $t_1$ | $\varkappa_1$ | $\lambda_1$ | $\mu_1$ | $\nu_1$ | $o_1$ | $\pi_1$ |
| 2–3 Suffix 2 | $\alpha_2$ | $\beta_2$ | $\rho_2$ | $\sigma_2$ | $\tau_2$ | $\chi_2$ | $\gamma_2$ | $\delta_2$ | $\gamma_2$ | $\xi_2$ | $\varepsilon_2$ | $t_2$ | $\varkappa_2$ | $\lambda_2$ | $\mu_2$ | $\nu_2$ | $o_2$ | $\pi_2$ |
| 3–4 Suffix 3 | $\alpha_3$ | $\beta_3$ | $\rho_3$ | $\sigma_3$ | $\tau_3$ | $\chi_3$ | $\gamma_3$ | $\delta_3$ | $\gamma_3$ | $\xi_3$ | $\varepsilon_3$ | $t_3$ | $\varkappa_3$ | $\lambda_3$ | $\mu_3$ | $\nu_3$ | $o_3$ | $\pi_3$ |
| 4–5 Suffix 4 | $\alpha_4$ | $\beta_4$ | $\rho_4$ | $\sigma_4$ | $\tau_4$ | $\chi_4$ | $\gamma_4$ | $\delta_4$ | $\gamma_4$ | $\xi_4$ | $\varepsilon_4$ | $t_4$ | $\varkappa_4$ | $\lambda_4$ | $\mu_4$ | $\nu_4$ | $o_4$ | $\pi_4$ |

**Fig. 3—Definitions of angular functions derived from Fig. 1 and definitions of elastic lamella constants in symbolic form all for use in the matrix equations**

| $1^\theta$ | $2^X$ | $2^Y$ | $2^\theta$ | $3^X$ | $3^Y$ | $3^\theta$ | $4^X$ | $4^Y$ | $4^\theta$ | $5^X$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $-H_{O_1}$ $-J_{E_1}$ $-K_{\pi_1}$ | $+F_{\lambda_1}$ | $+F_{\mu_1}$ $+E_{\nu_1}$ | $+H_{O_1}$ $-G_{E_1}$ $-L_{\pi_1}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $\theta^1$ |
| $+F_{\lambda_1}$ | $-C_{L_1+2}$ $-B_{X_{1+2}}$ | $+A_{Y_{1+2}}$ | $+F_{\lambda_{1-2}}$ | $+C_{L_2}$ $+B_{X_2}$ | $-A_{Y_2}$ | $-F_{\lambda_2}$ | 0 | 0 | 0 | 0 | $X^2$ |
| $+F_{\mu_1}$ $+E_{\nu_1}$ | $+A_{Y_{1+2}}$ | $-B_{\delta_{1+2}}$ $-C_{\gamma_{1+2}}$ $-D^{\varepsilon}_{\zeta_{1+2}}$ | $+F_{\mu_{1-2}}$ $+E_{\nu_{1-2}}$ | $-A_{Y_2}$ | $+B_{\delta_2}$ $+C_{\gamma_2}$ $+D^{\varepsilon}_{\zeta_2}$ | $-F_{\mu_2}$ $-E_{\nu_2}$ | 0 | 0 | 0 | 0 | $Y^2$ |
| $+H_{O_1}$ $-G_{E_1}$ $-L_{\pi_1}$ | $+F_{\lambda_{1-2}}$ | $+F_{\mu_{1-2}}$ $+E_{\nu_{1-2}}$ | $-H_{O_{1+2}}$ $-J_{E_{1+2}}$ $-K^{\pi}_{\pi_{1+2}}$ | $+F_{\lambda_2}$ | $+F_{\mu_2}$ $+E_{\nu_2}$ | $+H_{O_2}$ $-G_{E_2}$ $-L_{\pi_2}$ | 0 | 0 | 0 | 0 | $\theta^2$ |
| 0 | $+C_{L_2}$ $+B_{X_2}$ | $-A_{Y_2}$ | $+F_{\lambda_2}$ | $-C_{L_{2+3}}$ $-B_{X_{2+3}}$ | $+A_{Y_{2+3}}$ | $+F_{\lambda_{2-3}}$ | $+C_{L_3}$ $+B_{X_3}$ | $A_{Y_3}$ | $-F_{\lambda_3}$ | 0 | $X^3$ |
| 0 | $-A_{Y_2}$ | $+B_{\delta_2}$ $+C_{\gamma_2}$ $+D^{\varepsilon}_{\zeta_2}$ | $+F_{\mu_2}$ $+E_{\nu_2}$ | $+A_{Y_{2+3}}$ | $-B_{\delta_{2+3}}$ $-C_{\gamma_{2+3}}$ $-D^{\varepsilon}_{\zeta_{2+3}}$ | $+F_{\mu_{2-3}}$ $+E_{\nu_{2-3}}$ | $-A_{Y_3}$ | $+B_{\delta_3}$ $+C_{\gamma_3}$ $+D^{\varepsilon}_{\zeta_3}$ | $-F_{\mu_3}$ $-E_{\nu_3}$ | 0 | $Y^3$ |
| 0 | $-F_{\lambda_2}$ | $-F_{\mu_2}$ $-E_{\nu_2}$ | $+H_{O_2}$ $-G_{E_2}$ $-L_{\pi_2}$ | $+F_{\lambda_{2-3}}$ | $+F_{\mu_{2-3}}$ $+E_{\nu_{2-3}}$ | $-H_{O_{2+3}}$ $-J_{E_{2+3}}$ $-K^{\pi}_{\pi_{2+3}}$ | $+F_{\lambda_3}$ | $+F_{\mu_3}$ $+E_{\nu_3}$ | $+H_{O_3}$ $-G_{E_3}$ $-L_{\pi_3}$ | 0 | $\theta^3$ |
| 0 | 0 | 0 | 0 | $+C_{L_3}$ $+B_{X_3}$ | $-A_{Y_3}$ | $+F_{\lambda_3}$ | $-C_{L_{3+4}}$ $-B_{X_{3+4}}$ | $+A_{Y_{3+4}}$ | $+F_{\lambda_{3-4}}$ | $+C_{L_4}$ $+B_{X_4}$ | $X^4$ |
| 0 | 0 | 0 | 0 | $-A_{Y_3}$ | $+B_{\delta_3}$ $+C_{\gamma_3}$ $+D^{\varepsilon}_{\zeta_3}$ | $+F_{\mu_3}$ $+E_{\nu_3}$ | $+A_{Y_{3+4}}$ | $-B_{\delta_{3+4}}$ $-C_{\gamma_{3+4}}$ $-D^{\varepsilon}_{\zeta_{3+4}}$ | $+F_{\mu_{3-4}}$ $+E_{\nu_{3-4}}$ | $-A_{Y_4}$ | $Y^4$ |
| 0 | 0 | 0 | 0 | $-F_{\lambda_3}$ | $-F_{\mu_3}$ $-E_{\nu_3}$ | $+H_{O_3}$ $-G_{E_3}$ $-L_{\pi_3}$ | $+F_{\lambda_{3-4}}$ | $+F_{\mu_{3-4}}$ $+E_{\nu_{3-4}}$ | $-H_{O_{3+4}}$ $-J_{E_{3+4}}$ $-K^{\pi}_{\pi_{3+4}}$ | $+F_{\lambda_4}$ | $\theta^4$ |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | $+2C_{L_4}$ $+2B_{X_4}$ | $-2A_{Y_4}$ | $+2F_{\lambda_4}$ | $-2C_{L_4}$ $-2B_{X_4}$ | $X^5$ |

**Stiffness Matrix for Symmetrical Loading**

| $1^\theta$ | $2^X$ | $2^Y$ | $2^\theta$ | $3^X$ | $3^Y$ | $3^\theta$ | $4^X$ | $4^Y$ | $4^\theta$ | $5^Y$ | $5^\theta$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $-H_{O_1}$ $-J_{E_1}$ $-K^{\pi}_{\pi_1}$ | $+F_{\lambda_1}$ | $+F_{\mu_1}$ $+E_{\nu_1}$ | $+H_{O_1}$ $-G_{E_1}$ $-L_{\pi_1}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $\theta^1$ |
| $+F_{\lambda_1}$ | $-C_{L_1+2}$ $-B_{X_{1+2}}$ | $+A_{Y_{1+2}}$ | $+F_{\lambda_{1-2}}$ | $+C_{L_2}$ $+B_{X_2}$ | $-A_{Y_2}$ | $-F_{\lambda_2}$ | 0 | 0 | 0 | 0 | 0 | $X^2$ |
| $+F_{\mu_1}$ $+E_{\nu_1}$ | $+A_{Y_{1+2}}$ | $-B_{\delta_{1+2}}$ $-C_{\gamma_{1+2}}$ $-D^{\varepsilon}_{\zeta_{1+2}}$ | $+F_{\mu_{1-2}}$ $+E_{\nu_{1-2}}$ | $-A_{Y_2}$ | $+B_{\delta_2}$ $+C_{\gamma_2}$ $+D^{\varepsilon}_{\zeta_2}$ | $-F_{\mu_2}$ $-E_{\nu_2}$ | 0 | 0 | 0 | 0 | 0 | $Y^2$ |
| $+H_{O_1}$ $-G_{E_1}$ $-L_{\pi_1}$ | $+F_{\lambda_{1-2}}$ | $+F_{\mu_{1-2}}$ $+E_{\nu_{1-2}}$ | $-H_{O_{1+2}}$ $-J_{E_{1+2}}$ $-K^{\pi}_{\pi_{1+2}}$ | $+F_{\lambda_2}$ | $+F_{\mu_2}$ $+E_{\nu_2}$ | $+H_{O_2}$ $-G_{E_2}$ $-L_{\pi_2}$ | 0 | 0 | 0 | 0 | 0 | $\theta^2$ |
| 0 | $+C_{L_2}$ $+B_{X_2}$ | $-A_{Y_2}$ | $+F_{\lambda_2}$ | $-C_{L_{2+3}}$ $-B_{X_{2+3}}$ | $+A_{Y_{2+3}}$ | $+F_{\lambda_{2-3}}$ | $+C_{L_3}$ $+B_{X_3}$ | $-A_{Y_3}$ | $-F_{\lambda_3}$ | 0 | 0 | $X^3$ |
| 0 | $-A_{Y_2}$ | $+B_{\delta_2}$ $+C_{\gamma_2}$ $+D^{\varepsilon}_{\zeta_2}$ | $+F_{\mu_2}$ $+E_{\nu_2}$ | $+A_{Y_{2+3}}$ | $-B_{\delta_{2+3}}$ $-C_{\gamma_{2+3}}$ $-D^{\varepsilon}_{\zeta_{2+3}}$ | $+F_{\mu_{2-3}}$ $+E_{\nu_{2-3}}$ | $-A_{Y_3}$ | $+B_{\delta_3}$ $+C_{\gamma_3}$ $+D^{\varepsilon}_{\zeta_3}$ | $-F_{\mu_3}$ $-E_{\nu_3}$ | 0 | 0 | $Y^3$ |
| 0 | $-F_{\lambda_2}$ | $-F_{\mu_2}$ $-E_{\nu_2}$ | $+H_{O_2}$ $-G_{E_2}$ $-L_{\pi_2}$ | $+F_{\lambda_{2-3}}$ | $+F_{\mu_{2-3}}$ $+E_{\nu_{2-3}}$ | $-H_{O_{2+3}}$ $-J_{E_{2+3}}$ $-K^{\pi}_{\pi_{2+3}}$ | $+F_{\lambda_3}$ | $+F_{\mu_3}$ $+E_{\nu_3}$ | $+H_{O_3}$ $-G_{E_3}$ $-L_{\pi_3}$ | 0 | 0 | $\theta^3$ |
| 0 | 0 | 0 | 0 | $+C_{L_3}$ $+B_{X_3}$ | $-A_{Y_3}$ | $+F_{\lambda_3}$ | $-C_{L_{3+4}}$ $-B_{X_{3+4}}$ | $+A_{Y_{3+4}}$ | $+F_{\lambda_{3-4}}$ | $-A_{Y_4}$ | $-F_{\lambda_4}$ | $X^4$ |
| 0 | 0 | 0 | 0 | $-A_{Y_3}$ | $+B_{\delta_3}$ $+C_{\gamma_3}$ $+D^{\varepsilon}_{\zeta_3}$ | $+F_{\mu_3}$ $+E_{\nu_3}$ | $+A_{Y_{3+4}}$ | $-B_{\delta_{3+4}}$ $-C_{\gamma_{3+4}}$ $-D^{\varepsilon}_{\zeta_{3+4}}$ | $+F_{\mu_{3-4}}$ $+E_{\nu_{3-4}}$ | $-A_{Y_4}$ | $-F_{\mu_4}$ $-E_{\nu_4}$ | $Y^4$ |
| 0 | 0 | 0 | 0 | $-F_{\lambda_3}$ | $-F_{\mu_3}$ $-E_{\nu_3}$ | $+H_{O_3}$ $-G_{E_3}$ $-L_{\pi_3}$ | $+F_{\lambda_{3-4}}$ | $+F_{\mu_{3-4}}$ $+E_{\nu_{3-4}}$ | $-H_{O_{3+4}}$ $-J_{E_{3+4}}$ $-K^{\pi}_{\pi_{3+4}}$ | $+F_{\mu_4}$ $+E_{\nu_4}$ | $-H_{O_4}$ $-G_{E_4}$ $-L_{\pi_4}$ | $\theta^4$ |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | $-2A_{Y_4}$ | $+2B_{\delta_4}$ $+2C_{\gamma_4}$ $+2D^{\varepsilon}_{\zeta_4}$ | $+2F_{\mu_4}$ $+2E_{\nu_4}$ | $-2B_{\delta_4}$ $-2C_{\gamma_4}$ $-2D^{\varepsilon}_{\zeta_4}$ | $-2F_{\mu_4}$ $-2E_{\nu_4}$ | $Y^5$ |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | $-2F_{\lambda_4}$ | $-2F_{\mu_4}$ $-2E_{\nu_4}$ | $+2H_{O_4}$ $-2G_{E_4}$ $-2L_{\pi_4}$ | $-2F_{\mu_4}$ $-2E_{\nu_4}$ | $-2H_{O_4}$ $-2J_{E_4}$ $-2K^{\pi}_{\pi_4}$ | $\theta^5$ |

**Stiffness Matrix for Antimetrical Loading**

*Note.—*

First symbol (Bold upper case) denotes physical constant. Second symbol (Greek lower case) denotes trigonometric function, suffix denotes location. $-D^{\varepsilon}_{\zeta_{2+3}}$ to be read $-D\{\varepsilon_{(2+3)}+\zeta_{(2+3)}\}$, &c.

$2^{X,Y}$ is the movement of point 2 in the $X$ or $Y$ direction respectively, measured in inches, in the sense given by Fig. 3.

$2^\theta$ is the rotation of point 2, measured in radians, in the sense given by Fig. 3.

$X$, $Y^2$ is the external force acting at point 2 in the $X$ or $Y$ direction respectively, measured in pounds, and in the sense given by Fig. 3.

$\theta^2$ is the external moment acting at point 2, measured in inch pounds, in the sense given by Fig. 3.

Symmetrical loading implies a series of forces and/or moments of any magnitude acting so that any force or moment at any point in the range 1–4 is matched in magnitude and sign by one at the corresponding point in the range 1′–4′. A force of any magnitude may act at 5 in the $X$ direction. No moment or force in the $Y$ direction may act at 5.

Antimetrical loading implies a series of forces and/or moments of any magnitude acting so that any force or moment at any point in the range 1–4 is matched in magnitude and opposed in sign by one at the corresponding point in the range 1′–4′. Any force in the $Y$ direction or any moment may act at 5. No force in the $X$ direction may act at 5.

Any loading system whatsoever can be transformed into a pair of loading systems complying with the above conditions and can thus be dealt with.

**Fig. 4—"Stiffness Matrices" for symmetric and antimetric loading in terms of the constants derived from Figs. 1 and 3. These matrices cover any loading for any type of nine-node lamella and can be extended for any other odd-noded lamella roof by extrapolation**

inversion is carried out commercially at a very reasonable cost by a number of computing firms whose machines are programmed for these operations.

The coefficients for the nine-node lamella were first tabulated in general form (Fig. 3), so that by simply substituting the constants for any other physical system of the nine-node type the relevant coefficients can be obtained. Although the number of operations looks intimidating, the actual procedure is simple and can be performed by unskilled staff on hand calculators with gratifying rapidity.

The resulting equations, written in matrix form, appear in Fig. 4, thus the unknown displacements written above the square arrangement of coefficients are applied to these row by row, to equal the single force or moment written opposite the relevant row.

After inversion a new set of coefficients is obtained, arranged similarly to the original set. Now, however, the figures superscribed are no longer the unknown displacements, but the known applied forces, so that these forces multiplied into the coefficients row by row give the single displacement written opposite the relevant row, and the deformed picture corresponding to any loading scheme is thus obtained—see Fig. 5.

Obtaining the stresses in the member from the deformed picture of the structure calls for a similar procedure to that used in setting up the initial equations. Again, the steps have been tabulated in Fig. 5 and can be easily followed.

## Worked Example

In the worked example the following basic lamella was used :—Section 9·8in by 2·8in, length between nodes 8ft 4·5in. These dimensions were chosen to conform to experimental model work being carried out. Young's modulus 1,500,000 lb per square inch, Poissons ratio 0·36, shear modulus 550,000. The roof shape adopted was a circular arc of span = 50ft 3in and rise = 18ft 3in. The loading investigated was one of 1000 lb vertically at every nodal point.†

The standard analysis gave a deflection at the crown of about 0·4in, a maximal bending moment of 24,900in lb, and a direct compressive force of 2250 lb.

The rigorous analysis gave a deflection at the crown of 0·52in, a maximal bending moment of 21,569in lb, and a direct compressive force of 2251 lb. In addition, a bending moment about the weak axis of the lamella of 1163in lb, and a torque of 441in lb was found.

A check on the accuracy of the method is provided by the fact that the bending moment at the springings, which, by definition, was to be zero, works out at 110in lb for the major axis, and 45in lb for the minor axis, i.e. is practically zero.

## Comparison of Methods

The maximum bending moment is reduced by approximately 15 per cent in the rigorous analysis. It is interesting to recall that Otzen thinks a reduction of 25 per cent in the maximum bending moments is likely, basing this on some experiments, and that Crestin and some Canadian engineers have used a reduction of 17 per cent as an arbitrary figure. The direct compression in the members seems unaffected by the more exact method.

It is the bending about the minor axis of the lamella section, however, which shows up clearly in the rigorous analysis, and which the approximate method ignores. For the

† All these figures are typical of a timber roof. Lamella roofs are, of course, also constructed of concrete and pressed steel units.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | +1000 lb | 0 | 0 | +1000 lb | 0 | 0 | +1000 lb | 0 | 0 | +1000 lb |

Applied symmetric load

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $\theta^1$ | $X^2$ | $Y^2$ | $\theta^2$ | $X^3$ | $Y^3$ | $\theta^3$ | $X^4$ | $Y^4$ | $\theta^4$ | $X^5$ |

$\times 10^{-6}$

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 0·0158276 | 0·276521 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 45·24068 |

=

| | |
|---|---|
| $1^\theta$ | −0·0051 Rad. |
| $2^X$ | −0·157in |
| $2^Y$ | −0·321in |
| $2^\theta$ | −0·00101 Rad. |
| $3^X$ | −0·0397in |
| $3^Y$ | −0·210in |
| $3^\theta$ | +0·0038 Rad. |
| $4^X$ | +0·325in |
| $4^Y$ | −0·0286in |
| $4^\theta$ | +0·00387 Rad. |
| $5^X$ | +0·526in |

Resulting symmetric deformations

**Load condition × inverted matrix gives deflected shape**

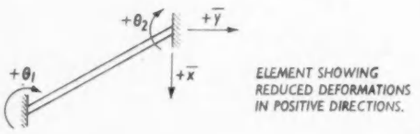
| | | | |
|---|---|---|---|
| Member 1–2 | $\theta_1$ | −0·0051 Rad. | $1^\theta$ |
| | $\bar{X}_1$ | −0·157in | $2^X$ |
| | $\bar{Y}_1$ | −0·321in | $2^Y$ |
| | $\theta_1$ | −0·00101 Rad. | $2^\theta$ |
| Member 2–3 | $\theta_2$ | −0·00101 Rad. | $2^\theta$ |
| | $\bar{X}_2$ | +0·1173in | $3^X-2^X$ |
| | $\bar{Y}_2$ | +0·111in | $3^Y-2^Y$ |
| | $\theta_2$ | +0·0038 Rad. | $3^\theta$ |
| Member 3–4 | $\theta_3$ | +0·0038 Rad. | $3^\theta$ |
| | $\bar{X}_3$ | +0·365in | $4^X-3^X$ |
| | $\bar{Y}_3$ | +0·1814in | $4^Y-3^Y$ |
| | $\theta_3$ | +0·00387 Rad. | $4^\theta$ |
| Member 4–5 | $\theta_4$ | +0·00387 Rad. | $4^\theta$ |
| | $\bar{X}_4$ | +0·201in | $5^X-4^X$ |
| | $\bar{Y}_4$ | +0·0286in | $5^Y-4^Y$ |
| | $\theta_4$ | 0 | $5^\theta$ |

**Deformations in reduced form**

| Deriving from ↓ / Stress resultant → | Direct force (compression +) | Bending in the major plane (inside of lamella in compression +) | | Bending in the minor plane (inside of lamella in compression +) | | Torque |
|---|---|---|---|---|---|---|
| | | Lower end | Upper end | Lower end | Upper end | |
| Reduced vertical movement $\bar{X}$ | $+\bar{X}\sigma\frac{\mathbf{B}}{2}$ | $+\bar{X}\chi\frac{\mathbf{F}}{2}$ | $-\bar{X}\chi\frac{\mathbf{F}}{2}$ | — | — | — |
| Reduced horizontal movement $\bar{Y}$ | $-\bar{Y}\lambda\frac{\mathbf{B}}{2}$ | $+\bar{Y}\sigma\tau\frac{\mathbf{F}}{2}$ | $-\bar{Y}\sigma\tau\frac{\mathbf{F}}{2}$ | $+\bar{Y}\rho\frac{\mathbf{E}}{2}$ | $-\bar{Y}\rho\frac{\mathbf{E}}{2}$ | — |
| Rotation $\theta_1$ | — | $-\theta_1\tau\frac{\mathbf{J}}{2}$ | $+\theta_1\tau\frac{\mathbf{J}}{4}$ | $-\theta_1\rho\sigma\mathbf{L}$ | $+\theta_1\rho\sigma\frac{\mathbf{L}}{2}$ | $\theta_1\frac{\mathbf{H}}{2}\rho\chi$ |
| Rotation $\theta_2$ | — | $-\theta_2\tau\frac{\mathbf{J}}{4}$ | $+\theta_2\tau\frac{\mathbf{J}}{2}$ | $-\theta_2\rho\sigma\frac{\mathbf{L}}{2}$ | $+\theta_2\rho\sigma\mathbf{L}$ | $-\theta_2\frac{\mathbf{H}}{2}\rho\chi$ |
| $\sum$ Summation of stress resultants | $\frac{\mathbf{B}}{2}\{\bar{X}\sigma-\bar{Y}\lambda\}$ | $\mathbf{F}/2\{\bar{X}\chi+\bar{Y}\sigma\tau\}$ $-\mathbf{J}/4\{2\theta_1+\theta_2\}\tau$ | $\mathbf{J}\cdot4\{2\theta_2+\theta_1\}\tau$ $-\mathbf{F}\cdot2\{\bar{X}\chi+\bar{Y}\sigma\tau\}$ | $\bar{Y}\rho\frac{\mathbf{E}}{2}$ $\mathbf{L}/2\{2\theta_1+\theta_2\}\rho\sigma$ | $\mathbf{L}\cdot2\{2\theta_2+\theta_1\}\rho\sigma$ $-\bar{Y}\rho\mathbf{E}\cdot2$ | $\frac{\mathbf{H}}{2}\rho\chi\{\theta_1-\theta_2\}$ |

Bold upper case symbols are physical constants for lamella unit as from lamella properties, Fig. 2. $\bar{X}$, $\bar{Y}$ are the reduced movements of a typical lamella (to be suffixed $\bar{X}_{12}$ for lamella unit 1–2, &c.). $\theta_1$, $\theta_2$ are the rotations as defined below (also to be suffixed for any particular unit). Greek lower case symbols are trigonometric functions from Fig. 3 (to be suffixed for any particular unit).

**General expressions for converting reduced deformations into stress resultants**




| Lamella unit, referred to nodes ↓ / Stress resultant → | Direct force | Bending in the major plane | | Bending in the minor plane | | Torque |
|---|---|---|---|---|---|---|
| | | Lower end | Upper end | Lower end | Upper end | |
| 1–2... ... ... ... ... ... ... | +2,251 lb | −110 lb in | +21,569 lb in | −45 lb in | +1,163 lb in | −441 lb in |
| 2–3... ... ... ... ... ... ... | +1,632 lb | +19,509 lb in | +8,832 lb in | +495 lb in | +257 lb in | −520 lb in |
| 3–4... ... ... ... ... ... ... | +1,448 lb | +10,856 lb in | −10,265 lb in | +93 lb in | −80 lb in | −8 lb in |
| 4–5... ... ... ... ... ... ... | +1,166 lb | −5,761 lb in | −16,677 lb in | −49 lb in | −126 lb in | +408 lb in |

**Stress resultants of the worked example as determined by general expressions from reduced deformations for the four typical lamella units**

**Fig. 5—The example Lamella in solution form showing the matrix inversion, the displacements for the actual loading case quoted, and the derivation of stresses from displacements**

conditions of the example worked, the maximal fibre stresses due to this secondary bending are of the order of 19 per cent of those due to the primary bending, and are incremental thereto. Thus, without taking the stresses due to torque and shear into account (which will further modify the results) it can be stated that the effect of the secondary bending about the weak axis of the lamella section is to cancel out the reduction obtained by the stiffness due to the indeterminacy of the structure, and that the figures of 25 per cent (Otzen) or 17 per cent (Crestin) should, in the interest of safety, be reduced to nil.

It is possible, too, that under certain conditions of loading and for certain sections of lamellas, the secondary bending stresses will be even higher than those found for the example, and that for important structures likely to be highly stressed this aspect should be investigated.

### Gable Ends

The effect of stiffening due to gable ends has so far been completely neglected, as the roof considered was a long roof, i.e. one where the gable ends are so far removed from the section considered so as not to influence it. In fact, this will be the case when the ratio of distance between gables to roof periphery exceeds 4 or so.

An attempt was made to obtain experimentally a curve connecting the stresses likely to be experienced in the middle of a roof which is not a long roof as a ratio of the long roof stresses, and plot this ratio against the length/periphery figure. Otzen gives a curve, but as his is based on only three points, it must be treated with suspicion.

In the present case it was considered that the stresses would bear a linear relation to the maximum deflections encountered ; also that the roof was sufficiently like a shell roof for a cardboard shell model, supported along the springings and closed at the ends by a stiff diaphragm to be employed. Various lengths of roof with identical peripheries were therefore constructed and loaded on the crown with a flexible, mercury-filled tube, and the maximum deflections measured. The resulting curve is shown on the graph Fig. 2, and will provide some guidance to the stress reductions obtaining for short as opposed to long lamella roofs.

# Tidal Flow Computations

By J. R. H. OTTER, B.Sc. (Eng.), M.I.C.E., and A. S. DAY, B.Sc.(Eng.),A.M.I.Struct.E.*

*The article summarises previous work on tidal flow computations and discusses the difficulties encountered in carrying out accurate computations of the water levels and current velocities in a tidal channel by mathematical analysis or numerical computation, whilst taking proper account of quadratic bed friction, shallow water effects and variations in the width, depth and side slopes of an actual channel. Pillsbury's analytical solution for an exponential estuary with level bed and vertical sides, assuming linear friction and omitting shallow water effects, is redeveloped and then extended to give a qualitative picture of the changes in flow due to the installation of a permanent or movable barrier. A method of approximation is indicated still further extending this solution to include quadratic friction and shallow water effects. Since acceptable accuracy is not attainable by analytical methods, numerical methods of calculation are discussed and reference made to previous work of Doodson and Dronkers with hand calculators and graphical methods and the great labour involved in such methods. The use of digital computers is recommended and reference made to Hansen's computer calculations for the Ems. A description is given of the organisation of numerical calculations based on the finite difference equivalents of the partial differential equations of flow, with consideration of the boundary conditions and initial values of the variables, the grid found to be most suitable and the desirable relations of the basic time and distance differences. A practicable computer programme to deal with an arbitrarily shaped channel in full generality is mentioned. A simpler programme is described in some detail to deal with the exponential equivalent of such rivers as the Thames, including the calculation of the effects of permanent or movable barriers, and of surges. Typical results of the simpler programme are given with comparisons with the corresponding analytical solution and with model test results.*

IN the design of river works it is necessary at times to determine the flow of the tide with some accuracy, but the mathematical equipment of a civil engineer is not usually sufficient for him to appreciate the complications of the equations underlying the problem, as they involve both the time and at least one distance variable which leads to the expression of the problem in the form of partial differential equations. Even for mathematicians, the work has proved very difficult as the equations are complicated by the way in which the areas and widths of the channels vary from place to place and time to time, and by the effects of bed friction which do not bear a simple mathematical relationship to the current. Many papers have been written on the subject, but the only mathematical investigation giving results of much value to the civil engineer was that made by Brigadier General Pillsbury[1] of the U.S. Army in 1938. Pillsbury, who had observed the relative simplicity of tidal flow in a natural trumpet-shaped estuary, showed that for a river with vertical sides and a level bed, with the width expanding exponentially towards the sea, and with the friction assumed to be proportional to the current, a general idea of the flow could be obtained analytically. Although his method was strictly only applicable where the tidal range was small compared with the mean depth of the estuary, the results of his analysis were confirmed qualitatively by comparison with the flow in the Delaware River. The writers arrived at a similar solution by a somewhat different path which enabled the picture to be extended to cover also the effects of the installation in such a river of a fixed or movable barrier.

The mathematical basis of this solution is given below, together with the more interesting results, to show the effects of barriers. It was also found possible to approximate the flow more closely by adopting a method given by Lamb in his *Hydrodynamics*, to take into account shallow water effects and Chezy friction. Although the picture which emerges is of great interest and shows all the main features of tidal flow in an estuary, it is still lacking in the required numerical accuracy.

An alternative approach to such problems is to express the equations in terms of finite differences and to solve the resulting equations by numerical calculation. An example of this approach was the solution given by Doodson[2] of the flow in a long, vertical-sided channel with parallel sides and a level bed, closed at one end and using the Chezy formula for friction. The sheer labour of the necessary arithmetic in such a method is daunting, and its application to an actual river by hand calculators is virtually impossible. Dronkers[3] in Holland has developed semi-graphical methods in such cases, using his method of characteristics, but here again to make full allowance for arbitrary river dimensions is time-consuming. However, the introduction of high-speed digital computers has completely revolutionised the position, as was shown by Hansen[4] in Germany in 1956, when he calculated the flow in the River Ems with quite astonishing accuracy. Independently of Hansen's work, the writers' firm prepared a similar computer programme, but although it eventually proved successful, the basis used for the formulation of the finite difference equations was not entirely suitable to this particular problem, and a reformulation on Hansen's method led to very successful programmes, economical both in time and cost.

Before the development of a programme for an actual river, it was thought desirable that a research programme should be developed for an exponentially shaped river with a level bed to simplify the input data and to keep the computations within the facilities of the Ferranti " Pegasus " computer which was selected for the work. Apart from very minor simplifications not affecting the accuracy of the results for the problem in hand, full account was taken of Chezy friction and shallow water effects, and the programme was designed to deal fully with the effects of either a fixed or a movable barrier. This programme is described in some detail below.

A full programme, taking into account all factors affecting one-dimensional tidal flow in any actual channel, has now been developed for the Ferranti " Mercury " computer and used on several specific flow problems. This programme can deal with problems such as a canal open to the sea at both ends as well as the usual problem of an estuary or river open to the sea at one end and controlled by a barrier or by upland water flow at the landward end.

### The Variables

It would perhaps be as well to recall the method of formulation of the differential quotients and finite differences required for this work. If a problem involves only the relationship between two quantities, one is said to depend on the other, and one of the quantities, usually the more fundamental of the two, is thought of as the independent variable, and the other as the dependent variable. An approximation to the rate of change of the dependent variable with respect to the independent variable can be obtained by taking the difference in the values of the dependent variable at two slightly different values of the independent variable, and dividing this difference by the difference in the values of the independent variable.

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Suppose the values of the position of a particle at two times $t_1$ and $t_2$ are $x_1$ and $x_2$, then the rate of change of distance with time, i.e. the velocity of the particle, is approximately $x_2-x_1/t_2-t_1$. In the limit when the difference in time is very small, this ratio becomes the differential quotient $dx/dt$. For numerical work on a computer, the quotient is not taken to the limit ; a finite value of $t_2-t_1$ is adopted as the basis of the calculations and referred to as $\Delta t$, and the corresponding values of $x$ can be written as $x|$ for the position further from the zero position of $x$ and $|x$ for the nearer position, this notation having been found useful for easier handling of the tidal flow differences. The origin of distance is pictured as being to the left of the variable. In finite difference terms, the finite difference equivalent of $dx/dt$ is then $(x|-|x)/\Delta t$.

In tidal flow problems there are several independent variables, one of which is always the time for which the tidal state is required. In the general case for full description of flow, three independent distance variables would be required for movement in the two plan dimensions and the depth below the surface. It is found, however, that variations of current with depth do not affect tidal profiles to an appreciable extent, and in most rivers the variation of current at right angles to the main stream can also be neglected in calculating tidal profiles. In the present work, therefore, two independent variables, $x$ and $t$, are involved, $x$ being the distance from some arbitrary point at the sea end of the estuary.

The quantities to be determined are the water level ($h$) and the velocity of the current ($u$) at any given time and place, and the equations of flow can be written as relationships between the differential quotients (or their finite difference equivalents) of these independent variables with respect to $x$ and $t$. Since however there are two independent variables, the form of the differential quotient used for one independent variable is meaningless and the forms used are respectively :

$$\frac{\bar{u}-\underline{u}}{\Delta t},\ \frac{u|-|u}{\Delta x},\ \frac{\bar{h}-\underline{h}}{\Delta t} \text{ and } \frac{h|-|h}{\Delta x}.$$

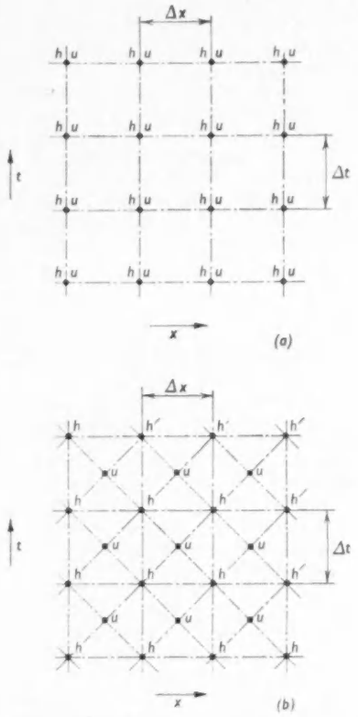
The upper and lower bars refer to the values of the current or level at one place at the end and the beginning of the time-interval $\Delta t$. The side bars refer similarly to the values of the current or level at the same time for places at the two ends of the distance interval $\Delta x$, one further from the origin of distance and the other nearer to it. When the time and distance are reduced progressively, the above four quotients become in the limit, the partial differential quotients which are written as

$$\frac{\partial u}{\partial t},\ \frac{\partial u}{\partial x},\ \frac{\partial h}{\partial t},\ \frac{\partial h}{\partial x}.$$

The equations of flow are for the purpose of mathematical analysis written as partial differential equations, and for numerical computation in the form of the finite difference equivalents.

The dependent variables can be visualised best in the form of a grid or mesh of points, each intersection representing one place and time ; the velocity of the current and the level at that time and place would be associated as dependent variables with that intersection. There are a number of different meshes possible (see for instance Southwell's books on relaxation methods) but the two most useful for computational work are the rectangular and diagonal grids shown in Figs. 1 (*a*) and 1 (*b*).

In addition to the independent and dependent variables described above, there are a number of other variables involved in the problem. The quantity of water passing any given cross section of the river at a given time ($Q$) can be considered as a dependent variable instead of the current velocity. The physical dimensions of the river also vary, and in the case of an actual river the dimensions involved in the work, such as the cross sectional area, the hydraulic mean depth and the surface width, all vary arbitrarily from place to place and time to time. Simplifications of the problem largely consist in simplifications in these variations. For instance, the assumption of vertical sides means that the width at any point




The letters *h* and *u* indicate the mesh intersections at which the levels and velocities are to be computed.

**Fig. 1 (*a*)—Rectangular mesh (*b*)—Diagonal mesh**

does not vary with time, and if the width of the river varies exponentially along its length, the ratio of the widths at two places at a definite distance apart is independent of the distance up the river.

Two other sets of variables involved are the values of the dependent variables $u$ and $h$ at the start of the calculations, referred to as the initial values, and their variations at the two ends of the river with time, referred to as the boundary conditions. For the initial values the numerical values of $u$ and $h$ must be known at a complete set of grid intersections throughout the length of the river and at the initial time ; in the case of the diagonal mesh, they are not required at the same time and place, but the number of values required is the same as for the rectangular mesh, where they are both required for each place at zero time. It will be seen intuitively that two sets of boundary conditions are required, but their choice varies with the problem. For a canal open to the sea at both ends, the tide curves at the two ends give the required boundary conditions. For a river, the tidal levels at the sea, and the landward current velocities (zero at a barrier), give the required boundary conditions.

The solution of the problem then resolves itself into the solution of the equations or the carrying out of the computations to determine the dependent variables subject to the initial values and boundary conditions of the given problem.

Tides in general comprise a number of components arising from the varying influences of the sun and the moon, the tidal periods of which are incommensurable. In most cases the components at any given time have periods of approximately twelve hours and twenty-four hours, the semi-diurnal and diurnal tides respectively. Analytical methods cannot satisfactorily deal with the general case nor is this usually necessary. Computer methods can, however, deal with any required input tide including one incorporating a surge. The tidal period ($T$) in angular terms is 360 deg. and the angular velocity of a semi-diurnal tide ($\omega$) is therefore about 30 deg. per hour. It will be seen that if the distance up-river is expressed as $x/c$ where $c$ is the celerity$=\sqrt{gH}$, the distance can then also be taken as an angular velocity. The equations are more simple in form when the substitutions $y=\omega t$ and $z=\omega t/c$ are made, both $y$ and $z$ then being angles. One can speak of a time of 30 deg. (equivalent to one hour) or to a distance up-river of 30 deg., that is, the approximate distance travelled by the tide in one hour.

## Analytical Approach

A full statement of the differential equations of one-dimensional flow has been made previously on numerous occasions, e.g. by Pillsbury, Doodson, Proudman and Dronkers. Two equations are required to define the flow, one of which expresses the conservation of mass and the other the conservation of energy.

The first equation, referred to as the " continuity " equation and expressed in the nomenclature given in the previous section, is

$$\frac{\partial b(H+h)u}{\partial x}+b\,.\,\frac{\partial h}{\partial t}=0 \quad . \quad . \quad . \quad . \quad (1)$$

The physical meaning of this equation is seen when it is expressed in terms of finite differences as follows :

$$(Q|-|Q)\Delta t+b\,.\,\Delta x\,.\,(\bar{h}-\underline{h})=0$$

The first term is the difference in the quantities of water passing the two ends of the reach of length $\Delta x$ in time $\Delta t$, which is clearly equal to the volume of water added in the same time to the reach, the surface area of which is $b\,.\,\Delta x$ and the rise $(\bar{h}-\underline{h})$.

The second equation referred to as the " dynamic " equation is

$$\frac{\partial h}{\partial x}+\frac{u}{g}\cdot\frac{\partial u}{\partial x}+\frac{1}{g}\cdot\frac{\partial u}{\partial t}+\frac{f\,.\,|u|\,.\,u}{g(H+h)}=0 \quad . \quad . \quad (2)$$

The physical meaning of the various terms is as follows :

(i) The first term is the slope of the river at the place and time considered, and represents the potential energy.

(ii) The second term is the rate of change in the velocity head with distance. In normal problems with a reasonably smooth change of current along the river this is negligible, and it has been neglected in what follows. For a river with a bore it would of course have to be taken into consideration.

(iii) The third term represents the acceleration or deceleration of the flowing water.

(iv) The last term takes into account the friction. As written, it will be seen to be a re-statement of the usual Chezy formula. The expression $|u|\,.\,u$ represents $u^2$ with the sign of $u$ as the direction of the friction turns with the current.

The equation of river shape expressing the

observation that the width of the river varies exponentially up-river is

$$b=b_0e^{-Kx} \quad . \quad . \quad . \quad . \quad (3)$$

The equation of continuity in a river complying with equation (3) then takes the form

$$\left(\frac{\partial}{\partial x}-K\right)(H+h)u+\frac{\partial h}{\partial t}=0 \quad . \quad . \quad (4)$$

The simplicity of the analysis derives from the constant term ($K$) appearing in the operator acting on the velocity. The approximations involved in the present analysis are as follows :

1. The tidal range is small compared with the mean hydraulic depth, which corresponds to the omission of shallow water terms. The term $h$ can then be neglected when compared with $H$ and the equations reduce to the forms :

$$H\left(\frac{\partial}{\partial x}-K\right).u+\frac{\partial h}{\partial t}=0 \quad . \quad . \quad . \quad (5)$$

$$\frac{\partial h}{\partial x}+\frac{1}{g}\cdot\frac{\partial u}{\partial t}+\frac{f.|u|.u}{g.H}=0 \quad . \quad . \quad . \quad (6)$$

2. The second approximation is that the friction is related linearly to the current velocity. This proposal was originally put forward by Lorentz and has been used by both Pillsbury and Dronkers in their work. The writers prefer to relate the friction to a constant of the dimensions of a velocity, the value of which makes the linear friction law approximately equivalent to the actual friction law in the higher ranges of velocity. Equation (6) then reduces to

$$\frac{\partial h}{\partial x}+\frac{1}{g}\cdot\frac{\partial u}{\partial t}+F.u=0 \quad . \quad . \quad . \quad . \quad . \quad (7)$$

where

$$F=\frac{f|\dot{u}|}{gH}=\text{constant.}$$

Differentiating equation (5) with respect to $x$ and equation (7) with respect to $t$, eliminating $h$, and making the substitution $c=\sqrt{gH}$, the equations reduce to the second order equation :

$$\frac{\partial^2u}{\partial x^2}-K\frac{\partial u}{\partial x}-\frac{F}{H}\cdot\frac{\partial u}{\partial t}-\frac{1}{c^2}\cdot\frac{\partial^2u}{\partial t^2}=0 \quad . \quad (8)$$

The substitution of $y=\omega t$ and $z=\omega x/c$ in place of $t$ and $x$ then reduces the equation to

$$\frac{\partial^2u}{\partial z^2}-\frac{Kc}{\omega}\cdot\frac{\partial u}{\partial z}-\frac{Fc^2}{\omega H}\cdot\frac{\partial u}{\partial y}-\frac{\partial^2u}{\partial y^2}=0 \quad . \quad (9)$$

In this simple form $z$ and $y$ are expressed as ratios to the time of the tidal cycle. If the cycle is taken as 360 deg., $z$ and $y$ are themselves expressed as angles.

It was then noted that if the coefficients of the first order terms in equation (9) were equal, the equation would have simple solutions and this is indeed approximately true in the case of rivers such as the Thames and Delaware. The introduction of the subsequently ubiquitous constant

$$q=\frac{Kc}{\omega} \quad . \quad . \quad . \quad . \quad . \quad (10)$$

reduces the equation of flow to the simple form

$$\frac{\partial^2u}{\partial z^2}-q\cdot\frac{\partial u}{\partial z}-q\frac{\partial u}{\partial y}-\frac{\partial^2u}{\partial y^2}=0 \quad . \quad . \quad (11)$$

This equation is solvable for terms of simple arbitrary functions, the solution being

$$u=\phi(z-y)+e^{qz}\psi(z+y) \quad . \quad . \quad (12)$$

By similar manipulation of equations (5) and (7) it can be shown that

$$\frac{\partial^2h}{\partial z^2}-q\frac{\partial h}{\partial z}-q\frac{\partial h}{\partial y}-\frac{\partial^2h}{\partial y^2}=0. \quad . \quad (13)$$

There is, therefore, a curious duality between $h$ and $u$, but this simplicity is somewhat misleading as the boundary conditions cause differences in amplitude, phase, &c.

For a simple harmonic input tide at the sea and a barrier at the landward end, the solutions for $h$ and $u$ are then

$$h=\hat{h}\left[\sin(z-y+\alpha)-\frac{e^{q(z-Z)}}{(q^2+1)^{\frac{1}{2}}}\sin(z+y-2Z)\right] \quad . \quad . \quad . \quad . \quad . \quad (14)$$

and

$$u=\frac{\hat{h}g}{c(q^2+1)^{\frac{1}{2}}}\left[\sin(z-y)+e^{q(z-Z)}\sin(z+y-2Z)\right] \quad . \quad . \quad . \quad . \quad . \quad (15)$$

where

$h=\hat{h}\sin(-y+\alpha)$ is the tide at the sea,

$\alpha=\tan^{-1}q$.

$c=\sqrt{gH}$.

$Z$ = distance of barrier from $z=0$ (at effective sea).

In an unrestricted river $Z$ will be large and the second terms of the above equations are negligible. The equations for the water elevations and current velocity in the unrestricted river are then

$$h=\hat{h}\sin(z-y+\alpha)$$

$$u=\frac{\hat{h}g}{c(q^2+1)^{\frac{1}{2}}}\sin(z-y) \quad . \quad . \quad . \quad . \quad (16)$$

To this approximation the tidal wave is thus a progressive wave travelling up-river, like events taking place at any point at any time at which $(z-y)$ is the same.

This solution predicts that the range of tidal levels and current velocity is constant throughout the length of the river which is approximately true for such rivers as the Thames and Delaware, where neither the currents nor the levels vary by more than about 20 per cent from their values at the mouth for a very considerable length of the river.

Substituting a value of $q\approx3$ based on the dimensions of the Thames, it can be shown that the current leads the elevation by about 72 deg. (the tidal period being taken as 360 deg.) and that high water occurs about half an hour before the changing of the current from flood to ebb.

Further work was done to give a better approximation to the actual flow in the river based on the perturbation method given in Lamb's *Hydrodynamics*,[5] taking into account quadratic friction and shallow water effects. The results did indeed give a much closer approximation to the flow, but the algebra, although essentially simple in principle, becomes quite involved in practice. The main result of these further approximations is that there are extra terms in the equation of flow (overtides) with periods harmonically related to the main tidal period, mainly an additional fundamental term together with a

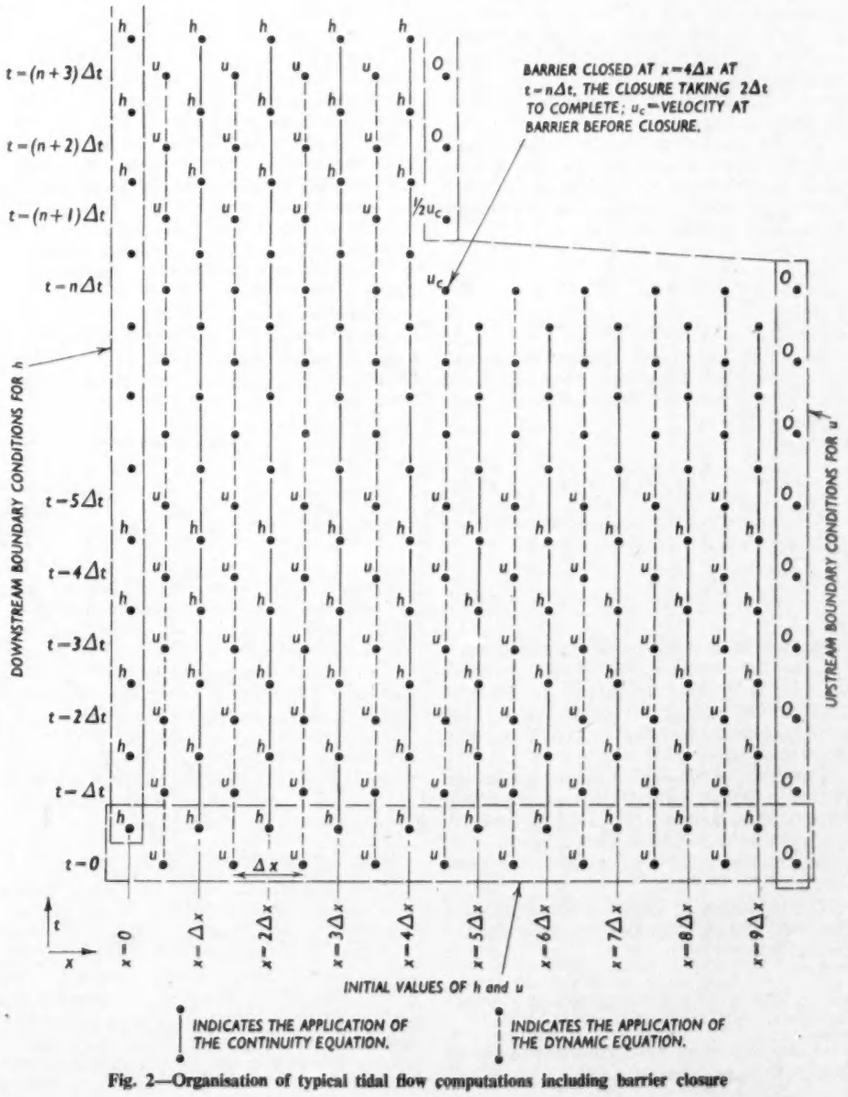



**Fig. 2—Organisation of typical tidal flow computations including barrier closure**

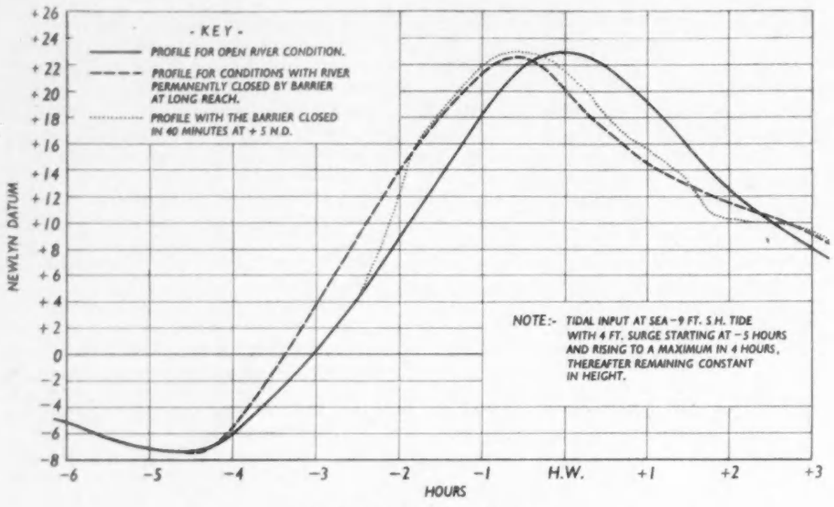

- KEY -
PROFILE FOR OPEN RIVER CONDITION.
PROFILE FOR CONDITIONS WITH RIVER PERMANENTLY CLOSED BY BARRIER AT LONG REACH.
PROFILE WITH THE BARRIER CLOSED IN 40 MINUTES AT + 5 H.D.
NOTE:- TIDAL INPUT AT SEA -9 FT. S.H. TIDE WITH 4 FT. SURGE STARTING AT -5 HOURS AND RISING TO A MAXIMUM IN 4 HOURS, THEREAFTER REMAINING CONSTANT IN HEIGHT.
NEWLYN DATUM
+26 +24 +22 +20 +18 +16 +14 +12 +10 +8 +6 +4 +2 0 -2 -4 -6 -8
-6 -5 -4 -3 -2 -1 H.W. +1 +2 +3
HOURS

**Fig. 3—Levels at Long Reach**

second harmonic and a smaller third harmonic. The terms are still simply related to $(z-y)$ and the amplitude of each overtide increases linearly up-river.

The main interest of the approximate analytical solution in connection with the problem of a fixed or movable barrier lay in the possibility of obtaining reasonable approximations to the actual flow in the river in an otherwise intractable case. Equations (14) and (15) can be used to determine the flow with a permanent barrier and the water levels and current velocities obtained are qualitatively in agreement with actual tests, although not sufficiently accurate for practical use.

To determine the effects of closing a movable barrier, assume that the barrier could be placed at point $Z$ at any selected time. The current velocity at the barrier before closing would then be

$$u_B=\frac{\hat{h}g}{c(q^2+1)^{\frac{1}{2}}}\sin(Z-y) \quad . \quad . \quad . \quad (17)$$

After closing it would be zero.

The difference in water level at the barrier at the same time in the open river and in the river with a permanent barrier would, from equation (14), be

$$\Delta h_B=\frac{\hat{h}}{(q^2+1)^{\frac{1}{2}}}\sin(Z-y) \quad . \quad . \quad . \quad (18)$$

If a current is stopped suddenly, there is a sudden change in water level equal to

$$\Delta h=u\sqrt{\frac{H}{g}}=\frac{uc}{g} \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

where $u$ is the velocity before the stoppage.

It will be seen that the difference in water level given in equation (18) is the same as that which would be produced by the sudden stoppage of a current with the velocity given in equation (17).

Consider further the conditions at the toe of the reflected wave which travels downstream with velocity $c$. After a time $\Delta y$ the wave front will have moved downstream a distance also equal to $\Delta y$ in non-dimensional terms.

The difference in current velocity between the unrestricted river and one with a fixed barrier is then

$$\Delta u=\frac{\hat{h}g}{c(q^2+1)^{\frac{1}{2}}}e^{-q\Delta y}\sin(Z-y) \quad . \quad (20)$$

Under the same conditions the jump in level at the same point would be

$$\Delta h=\frac{\hat{h}}{(q^2+1)^{\frac{1}{2}}}e^{-q\Delta y}\sin(Z-y) \quad . \quad (21)$$

and this is readily seen to be the difference in elevation between the unrestricted river and one with a fixed barrier.

To this approximation, therefore, when a barrier is closed instantaneously, conditions change from those appropriate to the unrestricted river to those appropriate to a river with a fixed barrier. In this sense the solutions of the basic second order equation have no transients, the conditions changing directly from one tidal state to another tidal state, not instantaneously at all points, but at the toe of the travelling wave.

An interesting corollary is that at the time when the levels in the unrestricted river and one with a fixed barrier would be the same, the current velocity would be zero in both; another is that it would not matter to this approximation when or in what manner (instantaneously, rapidly or slowly) the barrier were closed.

A further point of interest is that the height of the wave travelling downstream is inversely proportional to the width of the river at the point, and not, as has sometimes been said, inversely proportional to the square root of the width. The height of such a wave will decrease rapidly in accordance with the reciprocal exponential, and in the case considered would be negligible at the sea.

A matter often of practical importance is that the profiles for the unrestricted and restricted rivers are asymptotic as they approach the sea. This enables an unrestricted river to be approximated by a river with a barrier at the landward end.

There are a number of interesting physical deductions which may be made from this solution, perhaps the most important of which is that an estuary flowing in material which can be eroded tends to take up an exponential shape with a level bed, as has often been observed in the past. The reason is that when the maximum velocity exceeds that which would move the bed, the width of the river is increased until a state is reached when the maximum upstream and downstream velocities are approximately constant throughout the river, as in the analytical case described above.

An interesting alternative mathematical approach to this aspect of the tidal problem has recently been published by Abbott[9] of the Hydraulics Research Station, Wallingford.

## Computer Approach

Whilst the analytical research described above was in progress, work had also been proceeding on the development of a computer programme based on finite differences. It can be shown that the continuity equation (4) and dynamic equation (6) can be written in the forms

$$\bar{h}=h+\frac{\Delta t}{\Delta x}\cdot e^{\frac{K\Delta x}{2}}|h\,.\,u|-\frac{\Delta t}{\Delta x}\cdot e^{\frac{-K\Delta x}{2}}|h\,.\,u| \quad . \quad . \quad . \quad . \quad . \quad (22)$$

$$\frac{h|-|h}{\Delta x}=-\frac{1}{g}\cdot\frac{\bar{u}-u}{\Delta t}-\frac{f|u_{av}|\,.\,u_{av}}{g(H+h_{av})} \quad . \quad . \quad (23)$$

The suffix $av$ indicates the average over the interval.

Two slight modifications to the above equations are required to permit the programme to proceed. In the quadratic friction term the term $|u_{av}|\,.\,u_{av}$ is very closely equivalent to $|u|\,.\,\bar{u}$, and the dynamic

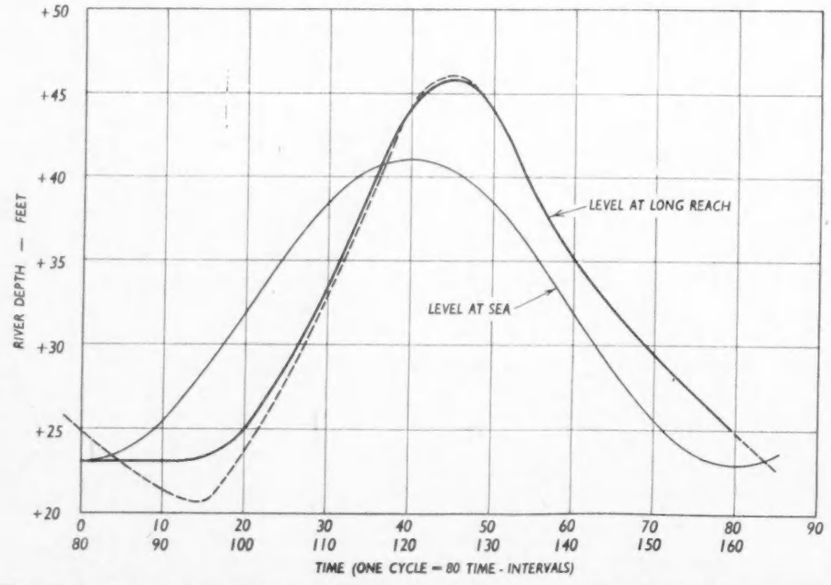

RIVER DEPTH — FEET
+50 +45 +40 +35 +30 +25 +20
LEVEL AT LONG REACH
LEVEL AT SEA
0 10 20 30 40 50 60 70 80 90
80 90 100 110 120 130 140 150 160
TIME (ONE CYCLE = 80 TIME - INTERVALS)

**Fig. 4—River levels at Long Reach due to 18ft range simple harmonic semi-diurnal tide at sea, starting from deadwater at 23ft level throughout river at $t=0$. Levels computed for two consecutive tide cycles. First cycle in full line, second in dotted line. Where full line only shown, second cycle coincides with first**

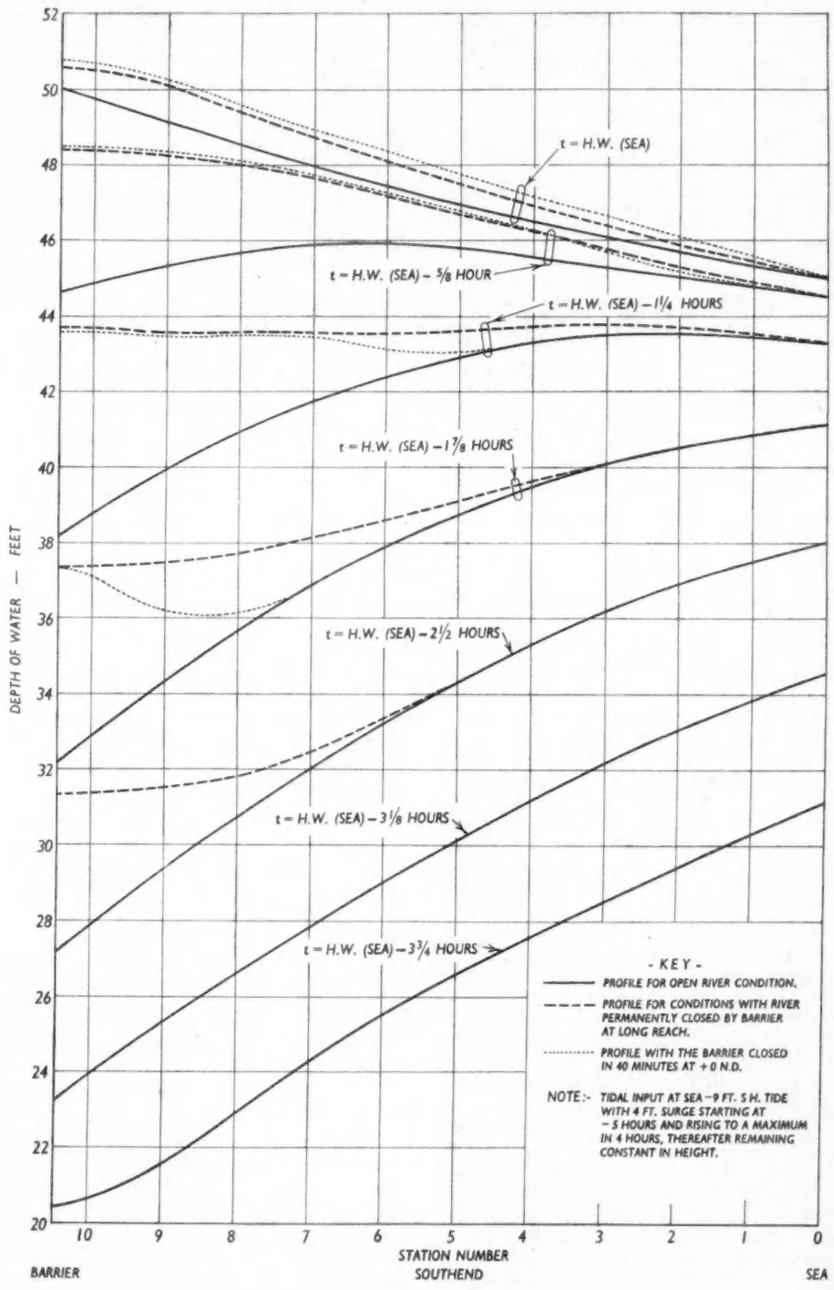

DEPTH OF WATER — FEET
STATION NUMBER
BARRIER
SOUTHEND
SEA
t = H.W. (SEA)
t = H.W. (SEA) – 5/8 HOUR
t = H.W. (SEA) – 1 1/4 HOURS
t = H.W. (SEA) – 1 7/8 HOURS
t = H.W. (SEA) – 2 1/2 HOURS
t = H.W. (SEA) – 3 1/8 HOURS
t = H.W. (SEA) – 3 3/4 HOURS
- KEY -
PROFILE FOR OPEN RIVER CONDITION.
PROFILE FOR CONDITIONS WITH RIVER PERMANENTLY CLOSED BY BARRIER AT LONG REACH.
PROFILE WITH THE BARRIER CLOSED IN 40 MINUTES AT +0 N.D.
NOTE:- TIDAL INPUT AT SEA −9 FT. S.H. TIDE WITH 4 FT. SURGE STARTING AT −5 HOURS AND RISING TO A MAXIMUM IN 4 HOURS, THEREAFTER REMAINING CONSTANT IN HEIGHT.

**Fig. 5—Profiles along river**

equation can then be simplified for the computer programme to the form

$$\bar{u} = \frac{g \cdot \frac{\Delta t}{\Delta x}(|h| - h|) + u}{1 + \frac{f \cdot \Delta t \cdot |u|}{H + h_{av}}} \quad . \quad . \quad . \quad . \quad (24)$$

In the continuity equation an approximation to the required later water level is necessary to determine the areas at either end of the reach being calculated. For this purpose one round of calculations is made assuming that the earlier level is an approximation to the later level and a second round is then made using the approximate $\bar{h}$ obtained from the first round. As this method of approximation converges extremely rapidly, no further iteration is necessary.

The organisation of the computations is shown in Fig. 2 as a diagonal mesh, in which the velocities are calculated at intervals half way between those used for the levels both in time and distance. Consideration of the mesh will show that if two levels adjacent in distance and at the same time and the velocity at the previous half time interval and half way between the two levels are known, then the application of the dynamic equation will give the velocity at the next half time interval. Similarly, if two velocities adjacent in distance are known and the height at the previous half time interval and midway between the velocities is also known then the continuity equation allows a calculation of the height at the next half time interval.

The initial values from which the calculations must start can be either dead-water with a constant river level and zero velocity (usually at low-water) or a previously determined set of water levels and velocities consistent with a tidal range reasonably similar to that which is to be investigated. The boundary conditions, are, of course, the water levels at the sea end of the mesh and the velocities at the landward end, usually taken to be zero.

A point of very considerable practical importance in connection with any computer programme for a second order partial differential equation is the ratio of the time interval to the distance interval. In an earlier programme on a somewhat different organisational basis it was found that considerable numerical oscillations took place in the figures for level and velocity and it was not at first appreciated why this should be so. However, it was found that much work had been done on this subject at Los Alamos in connection with neutron transport and gaseous diffusion,[8] and that Hansen[4] had also run into this difficulty in considering the two-dimensional computer programme for surges in the North Sea. Whilst a general solution for the stability of any given equation is not completely known it seems clear in this case that, provided $\Delta x/\Delta t$ is greater than the celerity of the wave ($c=\sqrt{gH}$) for the highest level in the river, the calculations are stable.

This programme was written with the Ferranti "Pegasus" computer which had ample storage and speed of operation for this particular programme.

Computations were made for an exponential river with a mean depth and flare coefficient corresponding to the average values for the Thames, from which a sample of the printed-out results is given in Fig. 6.

| A | | B | | C | |
|---|---|---|---|---|---|
| 016 | | 016 | | | |
| 31·13 | +3·13 | 31·13 | +3·36 | | |
| 30·31 | +3·35 | 30·31 | +3·35 | | |
| 29·43 | +3·31 | 29·43 | +3·31 | | |
| 28·50 | +3·21 | 28·50 | +3·21 | | |
| 27·52 | +3·09 | 27·52 | +3·09 | | |
| 26·54 | +2·92 | 26·54 | +2·92 | | |
| 25·51 | +2·55 | 25·51 | +2·55 | | |
| 24·35 | +1·76 | 24·35 | +1·76 | | |
| 22·96 | +0·51 | 22·96 | +0·51 | | |
| 21·52 | −0·39 | 21·52 | −0·39 | | |
| 20·67 | −0·79 | 20·67 | −0·79 | | |
| 020 | | 020 | | 020 | |
| 34·55 | +3·57 | 34·55 | +3·57 | 34·55 | +3·57 |
| 33·85 | +3·67 | 33·85 | +3·67 | 33·85 | +3·67 |
| 33·04 | +3·75 | 33·04 | +3·75 | 33·04 | +3·75 |
| 32·15 | +3·78 | 32·15 | +3·78 | 32·15 | +3·78 |
| 31·16 | +3·79 | 31·16 | +3·79 | 31·16 | +3·79 |
| 30·11 | +3·75 | 30·11 | +3·75 | 30·11 | +3·75 |
| 28·98 | +3·67 | 28·98 | +3·67 | 28·98 | +3·67 |
| 27·82 | +3·59 | 27·82 | +3·59 | 27·82 | +3·59 |
| 26·66 | +3·41 | 26·64 | +3·46 | 26·64 | +3·46 |
| 25·67 | +2·66 | 25·41 | +3·13 | 25·41 | +3·13 |
| 25·28 | +0·00 | 23·98 | +2·09 | 23·98 | +2·09 |
| 024 | | 024 | | 024 | |
| 37·98 | +3·49 | 37·98 | +3·49 | 37·98 | +3·49 |
| 37·46 | +3·67 | 37·46 | +3·67 | 37·46 | +3·67 |
| 36·85 | +3·84 | 36·85 | +3·84 | 36·85 | +3·84 |
| 36·13 | +3·99 | 36·13 | +3·99 | 36·13 | +3·99 |
| 35·29 | +4·12 | 35·29 | +4·12 | 35·29 | +4·12 |
| 34·34 | +4·20 | 34·33 | +4·21 | 34·33 | +4·21 |
| 33·30 | +4·17 | 33·34 | +4·26 | 33·24 | +4·26 |
| 32·33 | +3·87 | 32·07 | +4·23 | 32·04 | +4·27 |
| 31·74 | +2·90 | 31·07 | +3·70 | 30·75 | +4·23 |
| 31·57 | +1·49 | 30·89 | +2·05 | 29·37 | +4·16 |
| 31·37 | +0·00 | 31·27 | +0·00 | 27·94 | +4·08 |
| 028 | | 028 | | 028 | |
| 41·13 | +3·15 | 41·13 | +3·15 | 41·13 | +3·15 |
| 40·85 | +3·38 | 40·85 | +3·38 | 40·85 | +3·38 |
| 40·49 | +3·62 | 40·49 | +3·62 | 40·49 | +3·62 |
| 40·05 | +3·83 | 40·03 | +3·86 | 40·03 | +3·86 |
| 39·56 | +3·97 | 39·48 | +4·07 | 39·46 | +4·09 |
| 39·06 | +3·95 | 38·87 | +4·17 | 38·76 | +4·31 |
| 38·61 | +3·69 | 38·36 | +3·95 | 37·92 | +4·50 |
| 38·11 | +3·32 | 38·02 | +3·36 | 36·94 | +4·61 |
| 37·64 | +2·67 | 37·63 | +2·66 | 36·14 | +4·19 |
| 37·42 | +1·56 | 37·31 | +1·60 | 36·19 | +2·55 |
| 37·35 | +0·00 | 37·29 | +0·00 | 37·10 | +0·00 |
| 032 | | 032 | | 032 | |
| 43·28 | +2·36 | 43·28 | +2·37 | 43·28 | +2·38 |
| 43·42 | +2·68 | 43·39 | +2·73 | 43·38 | +2·74 |
| 43·63 | +2·94 | 43·56 | +3·03 | 43·50 | +3·10 |
| 43·72 | +3·07 | 43·65 | +3·16 | 43·45 | +3·37 |
| 43·65 | +3·18 | 43·63 | +3·20 | 43·24 | +3·64 |
| 43·54 | +3·21 | 43·55 | +3·22 | 43·05 | +3·75 |
| 43·48 | +3·07 | 43·44 | +3·11 | 43·10 | +3·48 |
| 43·43 | +2·75 | 43·42 | +2·76 | 43·39 | +2·80 |
| 43·45 | +2·16 | 43·42 | +2·19 | 43·45 | +2·20 |
| 43·53 | +1·27 | 43·51 | +1·28 | 43·42 | +1·33 |
| 43·63 | +0·00 | 43·60 | +0·00 | 43·57 | +0·00 |

**Fig. 6—Reproduction of part of computer output. Columns A, B and C refer to closures during the periods 16-20, 20-24 and 24-28 respectively. River levels are given in feet and velocities (signed) in feet per second. Each group of levels and velocities refer to the time period at the head of the group. Figures in each group read downwards from the sea to the barrier. $\Delta x$=24,000ft and $\Delta t$=one-eightieth of a semi-diurnal tidal period. The full computer results covered six closure times over a full tide cycle. The tide was a simple harmonic tide at the sea of 18ft range with a 4ft idealised surge**

As a matter of interest Fig. 3 based on the above results is given to show :

1. The water levels in the unrestricted river at Long Reach.

2. The water levels at Long Reach with a barrier permanently installed there.

3. The water levels at the barrier following the closure of the barrier about half tide. Similar data are available from the computation for points at intervals of approximately 5 miles along the river at time intervals of about half an hour. More frequent information could be printed out if it were required.

To show the effects of transients, Fig 4 shows the water levels at Long Reach starting from dead water and continuing over two cycles. It will be seen that the effects of starting from dead water (i.e. the initial transients) have disappeared very shortly after the first high water.

Fig. 5 shows the profiles of the water level for the three conditions mentioned above from which it will be seen that when the barrier is closed about half-tide, the water level jumps to the permanent barrier tide curve, and then follows it very closely, showing that, in this case also, the transients have disappeared very rapidly. At a time two hours after high water it will be noticed that there is a slight dip in the tide curve which is actually the return of the reflected wave due to the closing of the barrier, reflected back by a slight " mis-match " at the sea, that is, the width of the river at the sea is not infinitely great compared with that of the river. By a lucky accident an error was made in the computer programme during its development which had the effect of showing the wave effects caused by the injection of a quantity of water at a barrier in the river at different times during the tidal cycle. These results are somewhat too complicated to reproduce but they did indicate the way in which the amplitude of the resulting wave reduces as it approaches the sea and the effects of the river currents on the return wave from the sea. As a rule the amplitude of the return wave even at the barrier is small, and in general it does not coincide with maximum high water levels.

The tidal graphs given by this research programme were astonishingly close to those observed in a model of the Thames, the water levels being not more than perhaps 1ft different from those given by the model at any time or distance up river, even though the shape of the river had been idealised to an equivalent exponential shape.

It is interesting to compare these computer results with the analytical solutions given in the previous section with regard to the closure of barrier. Fig. 5 giving the profiles downstream at various times from closure to high water shows the changeover between the two conditions at the toe of the wave, and confirms the theoretical solution with regard to absence of transients. It was, however, found that while for closure times between low water and mid-tide, the relatively simple conditions corresponding to the analytical results obtain, after mid-tide the velocity in the river under quadratic friction and shallow water conditions is greater than analysis would predict, and closure then results in the water level at the barrier overshooting the permanently closed condition. For closure in the period just before high water the maximum water level is then greater than it would be if the barrier had been permanently installed.

In the case considered the computer and model results both indicate that for closures at or before mid-tide, the maximum high water level is not greater than it would have been if there had been no barrier.

The writers wish to acknowledge the valuable assistance given by Mr. John Holland, B.Sc. (Eng). in the analytical work described in this article.

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# Surface Stresses in Spur and Helical Gears

By W. A. TUPLIN, D.Sc., M.I.Mech.E.

*As the safe loading of gears is usually limited by consideration of surface stresses, it is necessary to develop some convenient means of expressing the relation between tooth load and surface stresses. This has been done many times in the past but usually with limitation to some restricted method of designing gear teeth. In this article is developed a working formula applicable to all spur and helical gears that may be generated by cutters conjugate to the British Standard basic rack.*

FORMULÆ for the load capacity of spur and helical gears have long been based on the assumption that the limiting factor is the maximum compressive stress, as deduced by the Hertz analysis, at the line of contact of a pair of teeth. The safe load may be limited in practice by the ability of the lubricant to keep the nominally contacting surfaces out of metallic contact, but as it is always possible to find a lubricant that will withstand the designed maximum load, this consideration need not be allowed to affect the main issue.

The possibility that hydrodynamic pressure in the oil film causes the maximum surface stress to be sensibly different from the Hertzian stress has been receiving intermittent consideration for some time past but with no result, so far, that is anything like so well established as the general validity of the Hertz analysis. The purpose of this article is to outline the development of a formula for load capacity assumed to be limited by Hertzian stress, which is determined by the loading per unit length of line of contact and by the radius of relative curvature of the surfaces at the line of contact. The problem is thus essentially one of gear geometry and the aim is to present the result in terms of the most readily determinable dimensions of the gears.

In any investigation of this sort it is essential to take into account all the variations that are possible in design when full use is made of the adaptability of the involute system. In the past it has often been considered sufficient to examine only the restricted conditions in which the difference between blank diameter and reference diameter is made equal to some arbitrary multiple of the normal pitch. This old-fashioned practice is an unnecessary restriction. Here it is assumed that the blank diameter may have any value within the range,

$$d_b=(p_n/\pi)(t\sec\sigma+V)$$

where $V$ may have any value that is less than $4-10/t\sec^3\sigma$ and greater than $1+20/t\sec^3\sigma$ and the basic rack has $\psi_n=20$ deg. and working depth $2p_n/\pi$.

This latitude in blank diameter is about as wide as possible consistently with avoidance of undercutting and sharp cresting of teeth.

The general principle adopted here is to present results for two cases.

(1) In which each gear has its maximum permissible value of $V$.

(2) In which each gear has its minimum permissible value of $V$.

*Notation*

(Suffix 1 refers to the gear with the smaller number of teeth and Suffix 2 to the other gear.)

$C$—Designed centre distance.
$d_b$—Diameter of tip cylinder$=(p_n/\pi)(t\sec\sigma+V)$.
$d_m$—Diameter of meshing cylinder.
$d_e$—Diameter of base cylinder.
$d_t$—Diameter of mean cylinder$=d_b-2p_n/\pi$.
$G_t$—$\dfrac{2\times\text{torque on gear}}{\text{Meshing diameter}\times\text{face width}}$
$M_1$—Torque applied to gear No. 1.
$p_a$—Axial pitch.
$p_n$—Normal pitch of basic rack.
$p_{en}$—Normal base pitch$=p_n\cos\psi_n$.
$R$—Radius of curvature.
$R_g$—Gear ratio$=t_2/t_1$.
$R_r$—Radius of relative curvature.
$S_c$—$\dfrac{\text{Load per unit length of contact line}}{\text{Radius of relative curvature of surfaces}}$
$t$—Number of teeth.
$V$—Blank-diameter factor.
$z$—$(V_1+V_2-4)/(t_1+t_2)\sec\sigma$.
$Z_h$—Zone factor for helical gears.
$Z_s$—Zone factor for spur gears.
$\sigma$—Helix angle at reference cylinder ($\sin\sigma=p_n/p_a$).
$\sigma_e$—Helix angle at base cylinder.
$\psi_n$—Flank angle of basic rack.
$\psi_t$—Transverse pressure angle of the meshing gears.

## Contact Stress

The maximum contact stress induced by a given normal load occurs where the radius of relative curvature of the contacting profiles has its minimum value, and this is, in general, where the smaller of the radii of the profiles at the point of contact has its minimum value. This condition is that in which the contact line is as close as possible to the base circle of the pinion consistently with avoiding division of the tooth load between two pairs of teeth. The most unfavourable condition is therefore that in which contact is just failing to be established near the tip of a tooth of the pinion ; the distance from the tip of a tooth to the corresponding profile of the next tooth, measured along the base tangent from the tip, is equal to the base pitch and this fact enables the position of the contact point of the loaded teeth to be established. The radius of relative curvature at the point of contact of two convex arcs of radii $R_1$ and $R_2$ is $R_1R_2/(R_1+R_2)$.

The quantity

$$\frac{\text{Load (lb) per inch length of contact line}}{\text{Radius (inch) of relative curvature of surfaces}}$$

is denoted by $S_c$ (as in British Standard practice) and this is a measure of the surface stress. The actual maximum compressive stress on the band of contact of steel surfaces is very nearly $(\sqrt{S_c})$ ton per square inch and

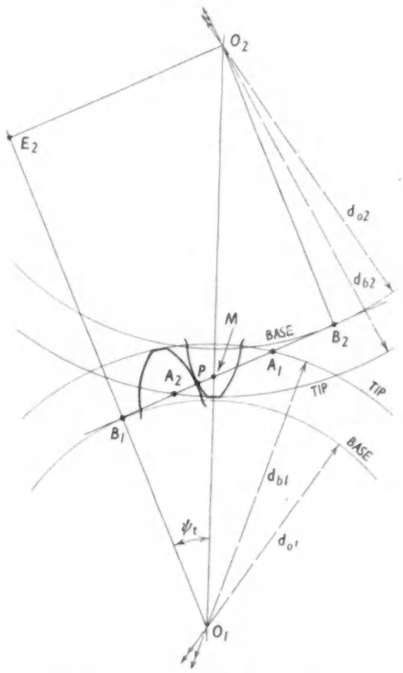



**Fig. 1—Contact of straight spur teeth**

the maximum shear stress induced in the material is about 0·3 ($\sqrt{S_c}$) ton per square inch.

### Determination of Minimum Radius of Relative Curvature of Tooth Profiles

In Fig. 1

$$B_1B_2=O_2E_2=\sqrt{(O_1O_2^2-O_1E_2^2)}=\sqrt{[C^2-(\tfrac{1}{2}d_{o1}+\tfrac{1}{2}d_{o2})^2]} \quad . \quad (1)$$

$$A_1B_1=\sqrt{(O_1A_1^2-O_1B_1^2)}=\sqrt{[(\tfrac{1}{2}d_{b1})^2-(\tfrac{1}{2}d_{o1})^2]} \quad . \quad (2)$$

Now

$$d_{o1}=(p_n/\pi)t_1\cos\psi_n \qquad d_{b1}=(p_n/\pi)(t_1+V_1) \quad . \quad (3)$$

$$d_{o1}=(p_n/\pi)t_2\cos\psi_n \qquad d_{b2}=(p_n/\pi)(t_2+V_2) \quad . \quad (4)$$

where

$t_1$, $t_2$ are the numbers of teeth in the gears,

$V_1$, $V_2$ are the quantities that relate the blank diameters to the reference diameters.

$C$ = designed centre distance.

$=\frac{1}{2}(d_{b1}+d_{b2})$ − working depth of teeth.

$=\frac{1}{2}(p_n/\pi)(t_1+V_1+t_2+V_2)-2(p_n/\pi)$ for B.S. teeth.

$=\frac{1}{2}(p_n/\pi)[t_1+t_2+V_1+V_2-4]$

$=\frac{1}{2}(p_n/\pi)(t_1+t_2)[1+z] \quad . \quad (5)$

where

$$z=(V_1+V_2-4)/(t_1+t_2)\sec\sigma \quad . \quad (6)$$

and $\sigma$ is the helix angle of generation which is zero for straight spur teeth.

So

$$B_1B_2=\tfrac{1}{2}(p_n/\pi)(t_1+t_2)\sqrt{[(1+z)^2-\cos^2\psi_n]} \quad . \quad (7)$$

$$A_1B_1=\tfrac{1}{2}(p_n/\pi)t_1\sqrt{[(1+V_1/t_1)^2-\cos^2\psi_n]} \quad . \quad (8)$$

Now

$A_1P$ = Base pitch $p_{no}=p_n\cos\psi_n$.

Hence, at $P$ the radius $PB_1$ of curvature of the lower profile is

$$R_1=A_1B_1-A_1P=\tfrac{1}{2}(p_n/\pi)t_1\{\sqrt{[(1+V_1/t_1)^2-\cos^2\psi_n]}-2\pi(\cos\psi_n)/t_1\} \quad . \quad (9)$$

The radius $R_2$ of curvature of the upper profile at $P$ is equal to $B_2P$ which is $B_1B_2-R_1$.

Hence the radius of relative curvature is

$$R_r=R_1R_2/(R_1+R_2)=R_1(B_1B_2-R_1)/B_1B_2 \quad . \quad (10)$$

For contact of the teeth at the point of contact of the meshing circles (the "mesh point") the radii of the profiles are $\frac{1}{2}d_{m1}\sin\psi_t$ and $\frac{1}{2}R_gd_{m1}\sin\psi_t$.

where $d_{m1}$ is the meshing diameter of the pinion

$R_g=t_2/t_1$

$\psi_t$ = transverse pressure angle.

The radius of relative curvature is therefore $\frac{1}{2}(\sin\psi_t)d_{m1}R_g/(1+R_g)$ and allowable load per unit width has often been estimated to be proportional to the quantity $d_{m1}R_g/(1+R_g)$.

The meshing diameter $d_{m1}$ normally approximates very closely to the "mean diameter" $d_1$ at the mid-depth of the pinion teeth, i.e. $d_1=d_b-2p_n/\pi$. As this diameter is more readily determinable from drawing dimensions than is $d_{m1}$, it is used here, and the relation between maximum $S_c$ and the tooth load per unit face width tangential to the mean cylinder of the pinion is expressed as

$$G_t=Z_sS_cd_1R_g/(1+R_g)$$

where $Z_s$ is a dimensionless quantity determined by the geometry of the gears.

The load (per unit length of contact line) normal to the contacting surfaces and therefore (in spur gears) perpendicular to the axis is equal to $S_cR_r$. This acts tangentially to the base cylinders and its component tangential to the mean cylinder (at mid-working depth of the teeth) of the pinion is $S_cR_rd_o/(d_b-2p_n/\pi)$.

Hence

$$Z_s=R_r[d_o/(d_b-2p_n/\pi)](1+R_g)/R_gd_1 \quad . \quad (11)$$

Fig. 2 gives the value of $Z_s$ for any combination of numbers of teeth with maximum permissible $V$ values. Fig. 3 applies similarly to teeth with minimum $V$ values. Interpolation on the basis of the $V$-value for the pinion enables the value of $Z_s$ for any combination of B.S. spur gears to be derived from Figs. 2 and 3.

### Effect of $V$ Value on $Z_s$

Comparison of Figs. 2 and 3 shows that for many tooth combinations there is a large variation in $Z_s$ between minimum and maximum values of $V$. For general purposes of preliminary design of spur gears, $Z_s$ may be taken as 0·15. When details of tooth dimensions are first considered in any particular application of spur gears, the aim should be to use high values of $V_1$, particularly for the pinion, in order to obtain a high value of $Z_s$ and therefore a high load capacity in relation to major dimensions. For example, preliminary design in a particular case might suggest

$$t_1=20,\ V_1=2$$
$$t_2=81,\ V_1=2$$

for gears to work at centre distance

$$C=\tfrac{1}{2}(p_n/\pi)(t_1+t_2+V_1+V_2-4)=50\cdot5(p_n/\pi).$$

Now if $t_2$ were to be reduced to 79, without change of $t_1$, maintenance of the same centre distance would require $(V_1+V_2)$ to be increased by (81−79)=2, i.e. from 4 to 6. The maximum permitted value of $V_1$ for $t_1=20$ is 4−10/20=3·5, and if this be adopted then $V_2$ might be 6−3·5=2·5 which is a permitted value for $t_2=79$. For the original case, Fig. 3, shows the value of $Z_s$ to be about 0·133 for $V_1=2$, while Fig. 2 shows $Z_s$ to be about 0·183 for $V_1=3·5$, giving a gain of about 40 per cent in load capacity.

### Errors in Base Pitch

The foregoing is based on the assumption that contact between any pair of teeth begins where geometrical analysis indicates that it will, but it must be remembered that such analysis assumes zero error in the spacing of the teeth. In practice, however, errors in base pitch may be comparable with the combined deflection of a pair of teeth by full load. If so, they invalidate the basic assumption and it is possible for the full load to be

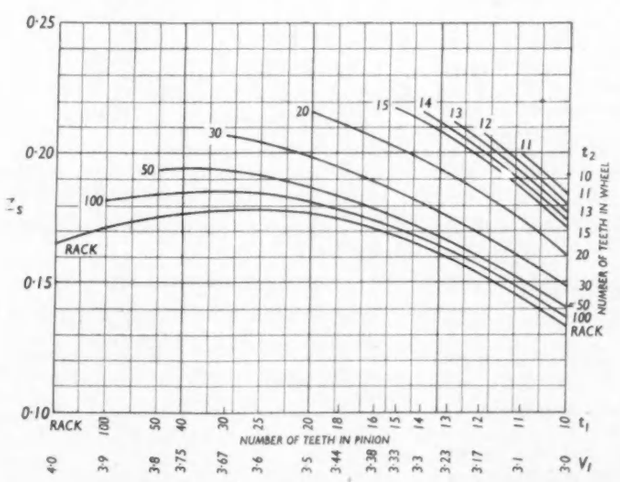



**Fig. 2—Values of $Z_s$ for high-precision spur gears with maximum $V$ values**

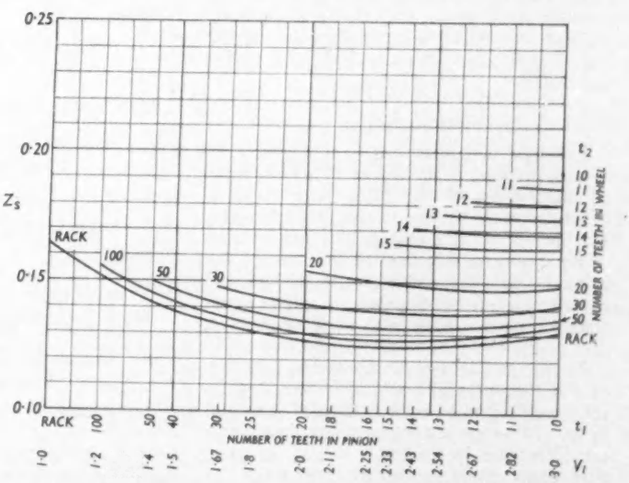



**Fig. 3—Values of $Z_s$ for high-precision spur gears with minimum $V$ values**

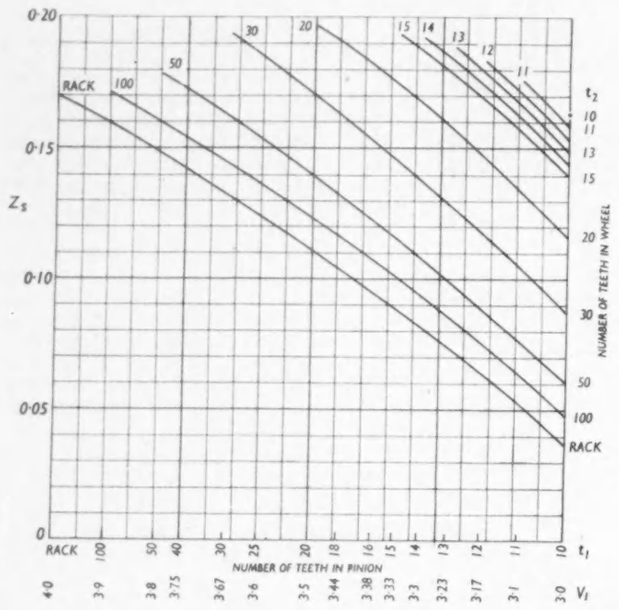



**Fig. 4—Values of $Z_s$ for commercial spur gears with maximum $V$ values.**

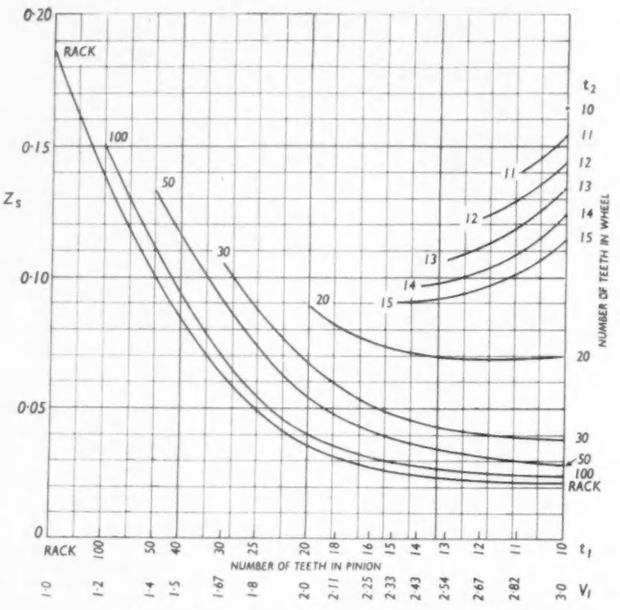



**Fig. 5—Values of $Z_s$ for commercial spur gears with minimum $V$ values**

taken by a single pair of teeth with contact at $A_2$ (Fig. 1) instead of $P$.

Now

$$A_2B_1 = B_1B_2 - A_2B_2$$
$$= \tfrac{1}{2}(p_n/\pi)t_1[(1+R_g)\sqrt{[(1+z)^2-\cos^2\psi_n)} - R_g\sqrt{[(1+V_2/t_2)^2-\cos^2\psi_n]}] \quad . \quad . \quad . \quad . \quad . \quad (12)$$

and this is the radius of curvature of the pinion tooth in this most unfavourable point of contact.

The radius of curvature is less than that which applies to the condition of perfect tooth spacing and the value of $Z_s$ is correspondingly reduced. Figs. 4 and 5 give, for maximum and minimum $V$ values respectively, the value of $Z_s$ for spur gears of what may be called " commercial quality " as distinct from high-precision gears. This distinction is approximately that between Grade C and the higher grades (A and B) in British Standard 436. It will be seen by comparing Figs. 3 and 5 that the change from high precision to commercial quality reduces $Z_s$ much more seriously for minimum values of $V$ than for maximum values. This view of the ill-effect of errors in base pitch in spur gears is perhaps unduly pessimistic, as normal " running-in " tends to invalidate it if the errors in the pinion are small and if it is made of material much harder than that of the wheel, because corrective wear may then occur. This is particularly the case if $R_g$ is a whole number.

## Helical Teeth

The lines of contact between the teeth of mating involute helicoidal gears are the lines of intersection of the tooth-flanks with a common tangent plane to the base cylinders. The lines of contact are straight, and inclined to the common direction of the axes of the gears at the base helix angle $\sigma_o$ and are spaced at a normal distance $p_{no}$, which is the common normal base pitch of the gears and that of the cutter that generated these teeth.

The lines of contact are limited to that part of the tangent plane which is bounded by the tip cylinders of both gears and their end faces. This zone of contact is thus a rectangle of width equal to the face width of the gears and length equal to the intercept ($A_1A_2$ in Fig. 1) of the tip circles on the common tangent to the base circles.

Let the normal pitch of the conjugate basic rack be $p_n$ and let the common axial pitch of the gears be $p_a$. Then the helix angle at the generating circle is

$$\sigma \text{ 2nd sin } \sigma = p_n/p_a \quad . \quad . \quad . \quad (13)$$

If the face width is an integral multiple of the axial pitch of the teeth, the total length of all the lines of contact is the same in all phases of engagement. It is equal to the area of the rectangular plane of contact divided by the spacing of the lines, i.e. face width $(A_1A_2)/p_{no}$. If the face width is not an integral multiple of the axial pitch but exceeds it, the total length of contact line varies with the phase of engagement, but this has only a negligible effect on the relation between torque and maximum contact stress.

The designed centre distance for helical gears is

$$C = \tfrac{1}{2}(d_{b1}+d_{b2}) - 2p_n/\pi$$
$$= \tfrac{1}{2}(p_n/\pi)[(t_1+t_2)\sec\sigma + V_1 + V_2 - 4]$$
$$= \tfrac{1}{2}(p_n/\pi)(t_1+t_2)(1+z)\sec\sigma \quad . \quad . \quad (14)$$

where $z$ is defined by (6).

The radius of the base circle of gear 1 is

$$r_{o1} = \tfrac{1}{2}(t_1/\pi)p_a p_{no}/\sqrt{(p_a^2 - p_{no}^2)}$$

and for gears conjugate with a basic rack of flank angle 20 deg. as in B.S. practice, this becomes

$$r_{o1} = \tfrac{1}{2}t_1(p_n/\pi)/\sqrt{(\sec^2 20\text{ deg.} - \sin^2\sigma)} \quad . \quad . \quad . \quad . \quad . \quad (15)$$

From this it can be deduced that

$$A_1B_1 = \tfrac{1}{2}(p_n/\pi)t_1\sqrt{[(\sec\sigma + V_1/t_1)^2 - 1/(\sec^2 20\text{ deg.} - \sin^2\sigma)]} \quad . \quad . \quad (16)$$

$$MB_1 = \tfrac{1}{2}(p_n/\pi)t_1\sqrt{[(1+z)^2\sec^2\sigma - 1/(\sec^2 20\text{ deg.} - \sin^2\sigma)]} \quad . \quad . \quad (17)$$

and hence that

$$B_1B_2 = \tfrac{1}{2}(p_n/\pi)t_1(1+R_g)\sqrt{[(1+z)^2\sec^2\sigma - 1/(\sec^2 20\text{ deg.} - \sin^2\sigma)]} \quad . \quad . \quad (18)$$

## Variation of Relative Curvature Along Line of Contact

As mating teeth make contact at any instant along a straight line, the contact conditions at any point on that line are substantially those applying to straight-line contact of cylinders. The line makes an angle 90 deg.$-\sigma_o$ with any plane perpendicular to the axis of the gear and consequently the radius of curvature at any point on the section of a tooth-flank by such a plane is equal to the radius of curvature of the flank (i.e. that of the section of the flank by a plane perpendicular to the straight line generator at the point) divided by sec $\sigma_o$. Hence, for example, the radius of curvature of the flank of the lower tooth in Fig. 1 at the point $P$ is $B_1P$ sec $\sigma_o$ because $B_1P$ is the radius of curvature of the section of the tooth by a transverse plane (that of the paper).

The radius of relative curvature varies from point to point along any line of contact, and its minimum value occurs at the inner limit of working depth of the pinion. The distribution of load along the line of contact of accurately meshing teeth is sensibly uniform[1] and safety requires that the total load on a line of contact be limited by the surface stress that it produces where the radius of relative curvature has its minimum value. This, however, is probably unduly pessimistic, as any over-strain at the critical point is likely to ease the surface pressure there, causing a redistribution of load along the contact line.

It has been observed that pitting of teeth usually starts (if it starts at all) at points near the middle of the working depth of the teeth. This suggests that it may be reasonable to take conditions at the mid-point of $A_1A_2$ as approximating to the critical ones ; this is the basis of the following analysis, but it is easy to develop an analysis on the basis of any other assumption as to the position of the contact point.

The distance between $B_1$ and the mid-point of $A_1A_2$ is

$$A_1B_1 - \tfrac{1}{2}A_1A_2 = A_1B_1 - \tfrac{1}{2}(A_1B_1 + A_2B_2 - B_1B_2) = \tfrac{1}{2}(B_1B_2 + A_1B_1 - A_2B_2).$$

The distance between $B_2$ and the mid-point is, similarly,

$$\tfrac{1}{2}(B_1B_2 + A_2B_2 - A_1B_1).$$

These distances are the radii of curvature of profiles touching at the mid-point of $A_1A_2$ and so the radius of relative curvature of helical tooth flanks in contact at this point is

$$R_r = [B_1B_2^2 - (A_1B_1 - A_2B_2)^2](\sec\sigma_o)/4B_1B_2 \quad . \quad . \quad . \quad . \quad . \quad (19)$$

A torque $M_1$ applied to a gear corresponds to a tooth load $2M_1/d_{o1}$, in a plane tangential

to the base cylinder and perpendicular to the axis. It is one component of the load $2M/d_{o1}\cos\sigma_o$ acting at right angles to the lines of contact whose total length is (Face width) $(A_1A_2)/p_{no}$.

Hence, the associated surface stress is

$$S_c=[(2M_1/d_{o1}\cos\sigma_o)/(\text{Face width})(A_1A_2)R_r]p_{no}.$$

Hence,

$$M_1=\tfrac{1}{2}S_c(d_{o1}\cos\sigma_o)(A_1A_2)(\text{Face width})R_r/p_{no}$$

and so the load tangential to the mean cylinder of the pinion per unit face width is :

$$G_i=2M_1/Fd_1=S_c(d_{o1}/d_1)\cos\sigma_o(A_1A_2)R_r/p_{no} \quad . \quad . \quad . \quad . \quad . \quad (20)$$

As in the case of spur gears, this may be written in the form

$$G_i=Z_hS_cd_1R_g/(1+R_g) \quad . \quad . \quad . \quad . \quad . \quad . \quad (21)$$

where $Z_h$ is a dimensionless quantity determined by the geometry of the gears.

Examination of a wide variety of combinations of numbers of teeth, helix angles and $V$-values shows remarkably little variation in $Z_h$ and a safe approximation is to write

$$G_i=0\cdot24S_cd_1R_g/(1+R_g) \quad . \quad . \quad . \quad . \quad . \quad (22)$$

for helical gears generated by B.S. cutters and having face width greater than the axial pitch of the teeth and any helix angle up to 45 deg.

For helical gears in which the face width is less than the axial pitch, it is reasonable to substitute for 0·24 the quantity

$$Z_s+(\text{Face width}/\text{Axial pitch})(0\cdot24-Z_s) \quad . \quad . \quad . \quad . \quad . \quad (23)$$

where $Z_s$ is the value derived from Figs. 2 and 3 for spur gears with the same numbers of teeth and $V$ values as the helical gears concerned.

## Comparison Between Straight and Helical Teeth

The value $Z_h=0\cdot24$ is higher than the value of $Z_s$ for any B.S. gears, but it must be remembered that the former is calculated on the assumption that the tooth load is divided between all the nominal lines of contact between the teeth that intersect the nominal contact plane at any instant. This implies high precision in normal base pitch of the teeth. In generated teeth, errors in this dimension are largely due to errors in the generating cutter and to deflection of its teeth and those of the gear teeth by the cutting forces because on any two teeth the points that will lie simultaneously in any contact plane are points that the generating cutter touches simultaneously ; errors in the machine itself have little effect on this dimension. In teeth generated by high-grade cutters with sharp edges and a light finishing cut, errors in normal base pitch are normally of the order of 2/10000in, but to set against this small quantity is the fact that steel gear teeth are stiff and that the normal force required to make a pair of teeth deflect by 2/10000in is of the order of 300 lb per inch width. Hence, the factor $Z_s=0\cdot24$ is applicable with safety only to helical gears of the highest grade of accuracy.

## Helical Gears of "Commercial Quality"

In this section consideration is given to the load capacity of helical gears in which the tooth spacing errors may be too great to justify the assumption that the load is spread over all the nominal lines of contact. Such gears are here described, for want of any more convenient method, as having "commercial quality," that term being interpreted in the same way as for spur gears. It is assumed that all the load must be carried (in certain phases of engagement at least) by a single pair of teeth making contact along a straight line in a common tangent plane to the base cylinders, and inclined at angle $\sigma_o$ to the direction of the axes of the gears.

If the ends of this line be in the end planes of the gears, its length is $F\sec\sigma_o$ where $F$ is the face width of the gears. If the face width is great enough, however, the ends of the line lie on the lines of intersection of the tangent plane and the tip cylinders of the gears. In that case the length of the contact line is $(A_1A_2)\operatorname{cosec}\sigma_o$ where $A_1A_2$ is the line so designated in Fig. 1.

In the following, the mean effective radius of relative curvature of contacting tooth-flanks is taken to be that at the point of intersection of the line of contact of the teeth with the line (indicated in Fig. 1 by $M$) of contact of the meshing cylinders. The radius of curvature of the section of a tooth flank by a plane perpendicular to the axis of the gear, at the meshing circle is $\frac{1}{2}d_m\sin\psi_t$ and the radius of relative curvature is this multiplied by $R_g/(1+R_g)$. As a plane normal to the tooth flank is inclined at angle $\sigma_o$ to a transverse plane, the radius of relative curvature of the normal section of the flanks at the meshing circle is $\frac{1}{2}d_m\sin\psi_t(\sec\sigma_o)R_g/(1+R_g)$ and the normal load per unit length of contact line is this expression multiplied by $S_c$. Further multiplication by $\cos\sigma_o$ gives the component of the load in a direction perpendicular to the axis and still further multiplication by $\cos\psi_t$ gives the equivalent load tangential to the meshing circle which, for this purpose, is taken to be the same as the mean circle.

If the length of contact line is limited by the end faces of the gears, it is equal to $F\sec\sigma_o$ and so the tangential load per unit of face width is :

$$G_i=\tfrac{1}{2}S_cd_m[R_g/(1+R_g)]\sin\psi_t\cos\psi_t\sec\sigma_o$$
$$=\tfrac{1}{2}S_cd_m[R_g/(1+R_g)]\sin\psi_n\cos\psi_n\sec^2\sigma \text{ very nearly}$$
$$=Z_hS_cd_1R_g/(1+R_g).$$

For

| | |
|---|---|
| $\sigma=0$ and $\psi_n=20$ deg. | $Z_h=0\cdot15$ |
| $\sigma=30$ deg. and $\psi_n=20$ deg. | $Z_h=0\cdot20$ |
| $\sigma=45$ deg. and $\psi_n=20$ deg. | $Z_h=0\cdot27$. |

The first of these agrees with the mean value already established for high-precision spur gears. The second, for a commonly used value of $\sigma$ is lower by 16 per cent than the 0·24 already adopted as a safe value of $Z_h$ for high-precision helical gears. The third value of $Z_h$, applying to a helix angle of 45 deg. (which is about the largest helix angle normally employed for helical gears), is greater than the general value of 0·24. To avoid an anomaly here, the value of 0·24 is adopted for $\sigma=45$ deg. With this, and an arbitrary smoothing-off between $\sigma=o$ and $\sigma=10$ deg., the results may be summarised as in Table I.

Table I—*Values of $Z_h$ for B.S. Generated Spur and Helical Gears*

| | $\sigma$ | High precision | Commercial quality* |
|---|---|---|---|
| $Z_s$ | 0 | 0·15 (but see Figs. 1 and 2) | 0·10 (but see Figs. 3 and 4) |
| $Z_h$ | 5 deg. | 0·24 | 0·12 |
| | 10 deg. | 0·24 | 0·15 |
| | 15 deg. | 0·24 | 0·16 |
| | 20 deg. | 0·24 | 0·17 |
| | 25 deg. | 0·24 | 0·18 |
| | 30 deg. | 0·24 | 0·20 |
| | 35 deg. | 0·24 | 0·22 |
| | 40 deg. | 0·24 | 0·23 |
| | 45 deg. | 0·24 | 0·24 |

* For all helical gears the face width is assumed to be not *less* than the axial pitch of the teeth ; for "Commercial Quality" the effective face width is not *greater* than $1\cdot4p_n\cot\sigma$.

The figures for "Commercial Quality" apply only if $F\sec\sigma_o$ is less than $A_1A_2\operatorname{cosec}\sigma_o$, and this corresponds approximately to the condition that $F$ is less than about $1\cdot4p_n\cot\sigma$.

The values of $Z_s$ for spur gears (i.e. $Z_h$ for $\sigma=o$) apply to values of $V_1$ and $V_2$ in the vicinity of 2. Where the values of $V_1$ and $V_2$ are known, the value of $Z_s$ should be determined by interpolation of the two relevant readings of Figs. 2 to 5.

## Comparison with Load-Capacity Formulæ in B.S. 436

The B.S. load capacity formula for helical gears may be expressed (very nearly) as

$$G_i=0\cdot33S_cd_1^{0\cdot8}R_g/(1+R_g) \quad . \quad . \quad (24)$$

Comparison with (21) shows that the value of this expression rises less rapidly with increase in $d_1$ than is the case with the expression derived from the Hertz relation. The reason for this is not absolutely established, the origin of (24) being empirical, but it is probably associated with the general tendency for large gears to have greater dynamic loads due to tooth pitch errors than have small gears of the same general standard of accuracy. There is much experience with gears designed in general accordance with (24) and this tends to confirm the appropriateness of the basic allowable surface stress factors and speed factors specified in B.S. publications. The stress factors constitute a source of information from which to derive corresponding factors for use in (21).

The average value of $d_1$, for the numerous pairs of gears from whose performances the B.S. allowable stress factors have been derived, is probably about 10in corresponding to a radius of curvature of about 1·5in for points on pinion teeth at or near the meshing cylinder. Most of the gears of this size do not run at very high speeds and so the dynamic loading on them is likely to be low.

Some of the B.S.I. information on allowable stress was derived from tests on discs in sliding contact with a radius of relative curvature of about 1·33in, which does not differ greatly from the 1·5in mentioned above. Accepting the B.S. basic allowable stress figures as reasonably well founded, corresponding figures for use in (21) may be derived from them by examining a case in which $d_1=10$ and the running speeds of the gears are low so that dynamic loads are negligible.

From (21) and (24) we have, writing $S_c=S_{c1}$ for the former

$$Z_hS_{c1}10=0\cdot33S_c10^{0\cdot8}$$

whence

$$S_{c1}=(0\cdot33/10^{0\cdot2}Z_h)S_c$$
$$=(1/4\cdot8\,Z_h)S_c.$$

Now for $d_1=10$ and $\sigma=30$ deg. (a commonly used value), Table I gives $Z_h=0\cdot2$ for commercial accuracy, which is known to be adequate for such a gear at low speed.

Using this

$$S_{c1}=1\cdot04S_c.$$

The coefficient of $S_c$ is so near to unity that it may be replaced by unity, and this means that the basic allowable $S_c$ values in B.S. 436 may be used in the equations derived here to give the value of tooth loading allowable at speeds low enough to make the dynamic effects of errors negligible and for periods short enough to make fatigue effect negligible.

It must be noted, however, that for a given pair of gears the value of $G_i$ allowable by B.S. formulæ falls as the speed rises by

virtue of the " speed factor " associated with the rotational speed of the gear concerned. A more rational (though slightly less convenient) course here is to estimate what repeated tooth load the gears can take in continuous running for the desired length of life and to subtract from that the estimated maximum load due to the dynamic effect of errors and inertia at the normal running speed. The remainder is the tooth load corresponding to the greatest torque that may be prudently applied to the pinion for the desired length of life.

### Summary

This article establishes, on the basis of broad approximation :

(1) A relation between tooth loading and the stress criterion $S_c$ for any pair of spur or helical gears.

(2) The fact that for any material the same basic allowable surface stress $S_{c\infty}$ may be used in both the B.S. 436 formula for allowable load and the one proposed here.

To develop practical formula for load capacity, it is necessary also to be able to estimate :

(3) Dynamic tooth load set up by speed and the errors in the gears and to discover,

(4) A relation between the ratio $S_c/S_{c\infty}$ (i.e. $S_c$ on the teeth/basic allowable $S_c$ for the material) and the number of times for which the stress $S_c$ may be applied to each tooth-flank before failure becomes likely.

(It may be useful to emphasise here that $S_c$ represents a stress determined by tooth loading and geometry, while $S_{c\infty}$ represents a stress associated with the endurance of the material of a gear. They are stresses that are compared when estimating probable life, and their symbols are similar, but they are essentially different in origin.)

Among the facts ignored so far in this analysis are :

(5) The one that owing to inevitable roughness of the surfaces of gear teeth, the local maximum $S_c$ is much greater than that corresponding to the nominal tooth loading and the nominal radii of curvature of the surfaces, and

(6) The one that the viscosity of the oil between gear teeth and their relative velocity at the nominal contact line may combine to cause the local maximum surface stress to be different from that indicated by the Hertz analysis.

These influences are, however, tacitly taken into account in the B.S. figures for basic allowable $S_c$ values for various gear materials, as these figures are based on extensive service experience over many years. In view of this it is reasonable to suggest that (5) and (6) may indeed be ignored provided that :

(7) Surface roughness is not appreciably greater than good commercial manufacturing methods have provided in gears in the last twenty years or so, and that

(8) The gears are lubricated with good quality oil viscous enough to prohibit metal-to-metal contact of the gear teeth under the known conditions of load and of movement of the contact line over the surfaces. Here, again, service experience is of great value, because it gives practical guidance in selection of oil.

It must be mentioned here that while modern additions to lubricating oil can give them adequate anti-scuffing properties at high speeds with lower viscosity than might formerly have been required, it has not been proved that there is any substitute for high viscosity of the lubricant for gears that normally operate at low speeds.

### Bending Stresses

This article deals solely with the limitation imposed on tooth loading by the value of the maximum surface stress.

There is also a limitation imposed by tensile stress due to the tooth-bending effect of the tooth load and this must, in principle, be taken into account, even though it is easily possible, in most cases, to design the gears so that the bending stress limitation is much higher than that imposed by surface stress. Comprehensive information on bending stress factors for spur gears with the full ranges of values of $V_1$ and $V_2$ is contained in reference 2.

### General Comment

The object in this article is to establish a working formula for the relation between tooth load and surface stress. By " working formula " is meant one that takes some account of the essential factors, but is not so complicated as to deter the average designer from using it. Formulæ of much greater complexity can easily be developed with the excuse of offering apparently higher precision. In practice, inevitable uncertainties in properties of gear materials, errors in manufacture and in mounting and in properties of lubricating oils make it meaningless to pursue fine points of geometry in developing a working formula. Any figure that may be used to define the load capacity of a pair of gears in specified conditions has a range of uncertainty of at least 10 per cent in each direction.

### References

[1] Trbojevic, M. D., 1957, The Engineer, August 9 and 16, " Load Distribution on Helical Gear Teeth."
[2] Jacobson, M. A., 1955, *Proc. Inst. Mech. E.*, Vol. 169, No. 33, page 587, " Bending Stresses in Spur Gear Teeth."

# Some Applications of " Deuce " to Diesel Engine Design

By T. J. WILLIAMS, B.Sc.*

*The article discusses the normal procedure of the design of diesel engines and illustrates the way in which the design calculations are interdependent. It reaches the conclusion that from economic and technical consideration the amount of calculations carried out for future designs will have to be greatly increased. A description is given of the way in which the Diesel Engine Division of The English Electric Company, Ltd., has made use of " Deuce " for design calculations. It is illustrated by brief descriptions of some of the two types of programmes of which use has been made. It is pointed out that whilst these programmes are mainly designed to be used independently it would be possible to arrange to carry out some of the interdependent calculations simultaneously.*

### Engine Design Problems

Up to the present, methods of diesel engine design have had a pattern common to many branches of mechanical engineering. The designer collects as much information as he can about existing engines and uses his own experience to produce a set of drawings which appear most likely to meet the specification. He will then calculate the loads on the components and the engine performance. The drawings must then be adjusted until, as far as can be seen at this stage, conditions are satisfactory. A large number of questions will remain to be resolved during experimental trials of the engine. Because of the complexity of the problem the technique of design is one of trial ; generally the drawings must be made before the calculations can be carried out. This method may be contrasted with that of the design of smaller and more simple mechanisms, which can be carried out by finding a simultaneous solution to a group of equations and criteria giving the drawing dimensions.

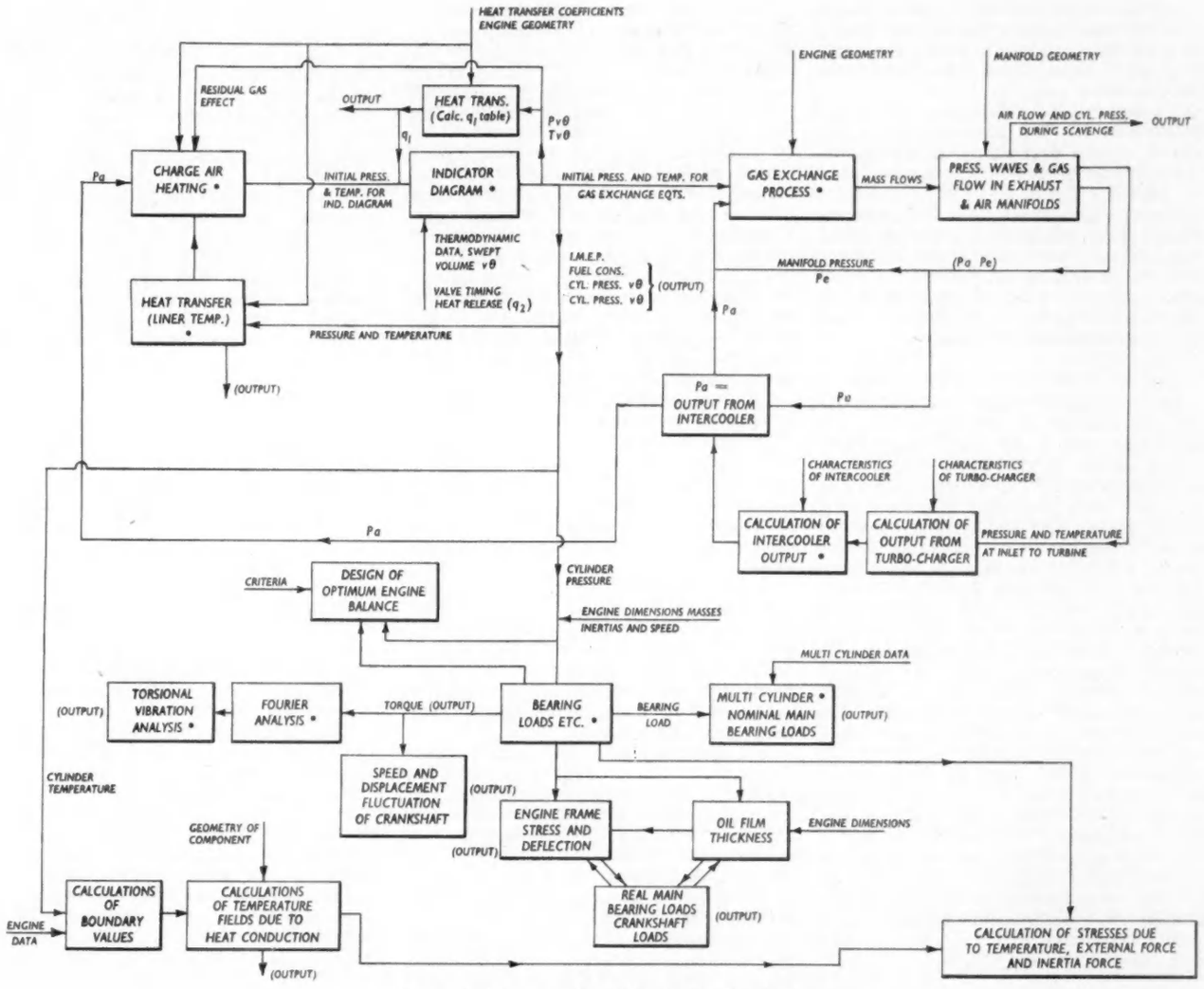
Although it is very unlikely that this latter system can ever be applied to diesel engines, most of the design calculations are interdependent, and should be carried out simultaneously. The diagram shows how some of the more important calculations are linked : for instance, it is necessary to know the charge pressure, among other things, before the theoretical indicator diagram can be calculated. The charge pressure is, however, dependent on the exhaust conditions, which are obtained from the theoretical indicator diagram via other calculations.

Use of the complete scheme of the diagram would require so much information about the geometry of the engine that an almost complete set of drawings would be required. This kind of calculation could, however, be of value during the project stages of design. The method of use would be to calculate the effect of changing variables of an existing engine. For instance, one might find the effect of increased maximum cylinder pressure on the piston temperatures of an existing engine and extrapolate this information to the projected engine. This technique is similar to that of the development shop, and, indeed, the diagram could be regarded as a scheme for an engine analogue. Although the calculations are shown as simultaneous they can often be used independently, not only for the kind of project work outlined above, but also to provide the designer with a reasonably accurate check on the dimensions of a component. For this purpose, however, the calculation must be carried out rapidly, so as not to hold up the design of other components.

Diesel engines have been in existence for over fifty years, and during that period most of the easier and more obvious improvements have been made. At the same time, competition from other types of prime mover has maintained the necessity for continued improvement. The increased application of project and design calculations as outlined above represents one way in which design methods may be improved ; it could also help to keep development costs to an economic level, where problems are now being solved in the development shop which could be solved more cheaply by calculation.

In view of these considerations the Diesel Engine Division of the English Electric Company decided to see what the " Deuce "

* Formerly of the Diesel Engine Division of the English Electric Company, Ltd.




**Some calculations associated with diesel engine design**

digital computer could do in lightening the burden of calculations on its design department. The Diesel Engine Division is particularly fortunate in having access to a "Deuce" and staff of programmers at the English Electric Company's Mechanical Engineering Laboratories (M.E.L.), so that no weighty deliberations about the cost of buying or hiring a computer were necessary before taking this step.

### Crankshaft Torsional Vibration Programme

The division's outstanding routine calculation was that of torsional vibration critical frequencies, amplitudes and stresses. Solution of this problem previously took anything from one day to a week, depending on the detail required. This seemed to be an obvious choice for the first programme, and accordingly the mathematics department at the Mechanical Engineering Laboratories were asked to programme this. The completed programme will calculate the natural frequencies, amplitudes and stresses for an eight-mass system (it can deal with up to thirty-two masses) in roughly four minutes per frequency. The programme was first used by the division in May, 1957, and has been in regular use ever since.

From this point the division has made steady progress in programming its problems. Even after the success of this first programme there has been from time to time some doubt as to whether the cost of a programme was justified. It has not always been possible to appreciate beforehand the potentialities of carrying out a particular calculation very rapidly, but in every case where a programme has been written the doubts have been replaced by regrets that more money was not spent on a larger programme.

Some other "Deuce" programmes are described below.

### Indicator Diagram Programme

Since many problems start from the engine gas pressure diagram it was decided that the theoretical indicator diagram should be programmed. The initial programme was completed by M.E.L. in about two months but has been under more or less continuous modification during the past year to make it faster, more versatile and more powerful. It is required to calculate the gas pressure in the engine cylinder at intervals of crank angle during the period when all valves are shut. The two equations governing this are the first law of thermodynamics (i.e. heat transferred = work done + change of internal energy), and the equation of state $PV=mRT$. An equation was constructed expressing these two facts and so arranged that the heat transferred and the swept volume were to be supplied as functions of crank angle. A step-by-step method is used, the gas composition being calculated at each step and the specific heat found by interpolating in tables with respect to gas composition and temperature.

To use the programme it is necessary to supply tables of swept volume versus crank angle, heat lost from the cylinder and heat supplied by combustion versus crank angle. The initial cylinder conditions and clearance volume must also be supplied. The output can be in one of two forms: either a table of pressure, temperature and work done at any desired intervals of crank angle, or a table giving crank angle, pressure and temperatures at maximum pressure, crank angle, temperature and pressure at maximum temperature, mean effective pressure and fuel consumption. If the crank angle at "exhaust valve opens" does not coincide with the crank angle at "inlet valve closes" there may be a slight error in calculation of the work done, since the programme assumes that the pressure drops to inlet pressure instantaneously when the exhaust valve opens. An automatic correction which is a good first approximation may be applied, however, if desired. This programme has proved to be exceptionally useful in investigation into the effect of combustion rates and combustion timing.

The facility for reading in combustion heat release and heat loss as a function of crank angle makes it possible to produce far more realistic diagrams than those obtained by assuming a constant volume–constant pressure combustion. Further, the concept of "expansion index" is not used, and there is thus no need to make arbitrary assumptions or guesses as to its value. The programme has been recently modified so that it will interpolate automatically between two sets

of results to give results at a predetermined peak pressure—this is useful in investigating the performance of various engine configurations when peak pressure is taken as a limiting factor.

The accuracy of the diagram calculation depends on the step size chosen : a step size of about 1 deg. during the combustion period and 5 deg. elsewhere gives an accuracy of about 2 per cent, and takes about three minutes of computer time. The time for a comparable hand computation is one and a half days. Since a considerable part of time is involved in reading in the programme a saving can be made by carrying out a number of consecutive calculations, when the programme is read only once.

### The Gas Exchange Programme

The most tedious calculation met so far has been the step-by-step solution of the equations relating the valve timing and engine cylinder conditions to the gas and air flows during the scavenging and charging process. These equations have been described elsewhere.* An average time to calculate the best arrangement of engine ports by hand computation is about three months. The job can be done on " Deuce " by ten to twenty calculations, lasting half an hour to an hour each. The procedure is to solve the relevant equations for assumed valve timings, cam shapes and cylinder release conditions. These assumptions must be adjusted until they are compatible with each other and the desired trapping pressure and air flows are obtained. Logically, the calculation should follow the loop shown in the diagram : Indicator diagram, gas exchange process, turbo charger, intercooler, charge air heating. This may be possible one day, but at present the procedure is to assume that the charge and exhaust pressures are constant and independent of the gas exchange process. The gas exchange equations have been programmed to take into account fluctuating manifold pressures.

### " Deuce " " Interpretive " Programmes

Experience of these three programmes led to the opinion that the cost of programming and the time spent by engineers in collaborating with the programmers would not be justified for small calculations and " one-off jobs." In fact the division seriously considered acquiring a small computer to be used directly by the engineering staff for the type of work which is normally done by slide rule. Fortunately, however, before any decision was made " Deuce " " interpretive " programming was introduced. This simplified system can be grasped in a few hours and the type of calculation for which it is intended can be programmed in one or two days. These advantages have to be paid for in increased computer time, but the ratio of hand computation time to computer time is still large. These interpretive methods have made it possible to programme a large number of calculations of a relatively simple nature, the effect has been greatly to increase the amount of calculation carried out in the early design stages, without requiring an increase in design staff. The same effect could not have been obtained by increasing the staff of computers and desk machines, because of the slow speed of this method of computation.

A brief summary of some interpretive programmes follows. Some of these were constructed by the Diesel Engine Division itself and some by the Mechanical Engineering Laboratories mathematics department.

*Swept Volume.*—This programme will calculate cylinder volume for a normal engine geometry at intervals of crank angle of $\frac{1}{2}$ deg. The time taken is twelve minutes.

*Piston Acceleration.*—Calculates piston acceleration for standard engine geometry at intervals of 2 deg. crank angle. The time taken is four minutes.

*Bearing Loads for Single-Cylinder Engines.*—A table of pressures (obtained from the indicator diagram programme) together with the engine geometry parameters and masses are used in this programme to calculate engine torque, side thrust on the cylinder, little end, big end and main bearing forces at 12 deg. intervals of crank angle. The time required varies, because it is possible to suppress any parts of the calculation which are not required for a specific application, but it is of the order of half an hour for a complete run.

*Vee Engine Bearing Loads.*—This is similar to the above, but carries out the calculations for a two-cylinder Vee engine. It also is arranged for maximum versatility by optional suppression of various parts of the calculation. A Fourier analysis of the torque output from both these programmes can be obtained by means of another " Deuce " programme ; this can be used for preparing data for the torsional vibration programme.

*Articulated Connecting-Rod Geometry.*—This programme was constructed to help in an investigation into the properties of articulated connecting-rods. It calculates piston displacements, accelerations and the angular velocities of the rods about the pins.

*Articulated Connecting-Rod Loads.*—This programme is used in conjunction with the above. It calculates (taking into account inertias) the loads on all the bearings, and the forces in the rods and big-end bolts.

*Nominal Multi-Cylinder Main Bearing Loads.*—The nominal main bearing load is taken as half the sum of the load vectors due to the cylinders on each side of the bearing. A table of single-cylinder main-bearing load obtained from one of the previous programmes together with the cylinder phasing corresponding to the firing order is the input for this programme.

*Cyclic Speed and Displacement Fluctuations of a Multi-Cylinder Engine.*—The torque crank angle table of a single-cylinder engine is summed to give a multi-cylinder engine torque curve. Successive integration of this leads to factors giving the cyclic speed and displacement fluctuations.

### Other Programmes

This does not exhaust the list of interpretive programmes, in fact the engineering research department of the division is at work continuously on new programmes, some of which may be the subject of a separate report. In particular, work has been carried out on calculation of heat transfer from the cylinder. This programme can be used to form a loop in the indicator diagram calculation as illustrated. In general, the division's experience of " Deuce " is that whilst there has been no net saving of engineers' time there has been a great increase in the amount of calculation carried out. It has also been possible to put to use fundamental principles and results of research whose application would have otherwise been impracticable. The potentialities of " Deuce " in diesel engine design have not yet been fully realised, as can be seen from the illustration where the asterisks indicate calculations whose programmes have been completed.

### Acknowledgment

The author would like to express his thanks to Mr. A. V. Wilkin, general manager Diesel Engine Division, the English Electric Company, Ltd., for permission to publish, and to Mr. N. D Whitehouse, chief of engineering research, Diesel Engine Division, for help in preparing this article.

* Williams, T., Pullman, W. A., " A Method of Valve Timing Design for Two-Stroke-Cycle Engines," *Journal of the Royal Aeronautical Society*, July, 1957.

# John Rennie, The Albion Flour Mill and Bankside

By A. K. BRUCE

THE foot passenger who crosses to the Surrey side of Blackfriars Bridge will notice, on the left hand, the bridge and viaduct which, since 1864, has carried the line of the former London, Chatham and Dover Railway. Immediately south of the bridge and between the railway and Blackfriars Road there is a range of railway buildings and at a short distance from the river an opening on the east side of the pavement gives access to a flight of steps leading down to an underground footway. This runs below the buildings and the railway to another flight of steps leading up to what was formerly known as Holland Street, now renamed Hopton Street. Adjacent to the subterranean passage is an arched opening which, though traversing the width of the railway viaduct, is not used for traffic. This tunnel marks the site of Holland Street, which, prior to the coming of the railway, ran east from Great Surrey Street (now Blackfriars Road) and terminated in the present Sumner Street. Horwood's map (1799) shows the southern end of Blackfriars Bridge as debouching on to a small square named Albion Place. This joined a short length of street called Albion Street, the thoroughfare continuing thence as Great Surrey Street. The famous Albion Flour Mill stood immediately adjacent to the east side of Albion Place, from which, indeed, the Mill may likely have taken its name. The frontage was on the river bank and contemporary drawings show the building to have had quite an imposing appearance. The old Blackfriars Bridge (called for a short time William Pitt Bridge) was built from the designs of Robert Mylne and opened for vehicular traffic in November, 1769, though foot passengers had used it since 1766. The existing bridge (designed by Joseph Cubitt and widened during 1907–09) was opened in November, 1869, and it is to be noted that whereas the gradient on the old bridge was originally 1 in 16 (later reduced to 1 in 24), the steepest gradient on the present bridge is 1 in 40. The adjacent railway bridge dates from about the same time as the present road bridge, consent for its construction having been obtained by the London, Chatham and Dover Railway Company during 1862. When receiving sanction for the construction of the bridge the railway company undertook to provide, for the use of the public, the underground passage already referred to.

That the ground adjoining the south end of Blackfriars Bridge can be regarded as a technological shrine is due not solely to the former existence there of an epoch-making though short-lived mill. It is due also to the singular eminence of certain men whose genius and labours are here remembered though not as yet recorded by any memorial on the site. Conspicuous among them was John Rennie, who designed the mill work, dealt with its construction and installation and brought the equipment into successful operation. No reference to Rennie could omit mention of his training for the profession which he was to adorn, the particulars of this training being specially significant for us at a time when, as to-day, the question of technical education has become a matter not only of unceasing discussion but of vast national expenditure. As a boy at Phantassie, East Lothian (where he was born nearly two centuries ago, actually on June 7, 1761), Rennie showed an interest in things mechanical which—as pointed out by Professor Rankine—was " strengthened and cultivated by his frequent visits, when a schoolboy, to the workshop of that skilful millwright, Andrew Meikle." After spending some time at the parish school, he entered the high school of Dunbar where, under Gibson—a teacher of great ability—Rennie studied mathematics and natural philosophy " with such success as to be able to act as Gibson's substitute for six months, about the year 1778." He had previously spent two years as an apprentice millwright in Meikle's workshop, so that by the time he entered the University of Edinburgh Rennie was exceptionally well qualified to profit from the lectures of John Robison (professor of natural philosophy) and Joseph Black (professor of chemistry). It is particularly interesting to note that during his three years at the University all Rennie's vacations were spent in Meikle's workshop at Knowsmill, near Phantassie. Meikle—the son of the James Meikle who set up the first winnowing machine seen in Scotland—was at the time developing his threshing machine which, later on, was to prove of immense value to agricultural industry though bringing little pecuniary benefit to its inventor. The importance of Meikle's contributions to the training of John Rennie can hardly be estimated and Rankine has justly pointed out that " one of Meikle's claims to distinction is that of having been the first master of the great engineer, John Rennie." We see something of the influence of Meikle in the development of Rennie's dredging machine, diving bell and other of his inventions, nor can it be doubted that to his training in a millwright's shop and his work as a practising millwright Rennie owed much of his valuable knowledge of men.

It was during 1783, shortly after the completion of his three years at Edinburgh University, that Rennie, introduced by Professor Robison, first met James Watt, who, after seeking and obtaining a personal recommendation from Robison, engaged the services of Rennie in connection with the design, manufacture and installation of the millwright work at the Albion Flour Mill. The terms of his reference did not extend to the Boulton and Watt steam engines, though Rennie must have been well acquainted with their details, having spent some time in Birmingham during the autumn of 1784, examining the work then in hand at Soho. Late in November, 1784, he left Birmingham for London, where he was to remain domiciled for the remainder of his life. While the history of the Boulton and Watt engines for Albion Mill is too well known to need recapitulation here, it may be mentioned that as late as November, 1782, Watt, writing to Boulton, had remarked how " There is now no doubt but that fire engines will drive mills, but I entertain some doubts whether anything is to be got by them." Certainly the history of the Albion Mill engines was, at the outset, a chequered one. That there could be no reflection on Rennie is clear from the fact of the engines having been specifically excluded from his supervision ; indeed, the trouble with the first of the engines—which were of 50 h.p. nominal, operating at a steam pressure of 5 lb per square inch gauge—seems to have been due to sheer lack of knowledge on the part of the fitter who dealt with the erection and first adjustments. Reports suggest that there was excessive noise and we find Watt (writing to Boulton in March, 1786) regretting that " so many things are amiss at Albion Mill, and that you have lost your good opinion of double (double-acting) engines, while my opinion of them is mended. The smoothness of their going depends on the steam regulators being opened a little before the vacuum regulators, and not opened too suddenly, as indeed the others ought not to be, otherwise the shock comes so violently in the opposite direction that no pins or brasses will stand it. Malcolm has no notion how to make gear work quietly, nor do I think he properly understands it." In the end, Murdock was summoned from Cornwall and under his direction satisfactory operation was established. The engines were not the first erected in London to have Watt's parallel motion. The first engine started up in London with this gear installed was the one erected at Whitbread's brewery in Chiswell Street, an installation wherein the millwright work involved in the change-over from horse-wheel drive to steam engine drive was also supervised by John Rennie (see THE ENGINEER, February 28, 1958, page 312). Watt is on record as having protested strongly against the lavish facilities which appear to have been afforded, at the Albion Mill, for public inspection of the prototype equipment installed there. He was, of course, deeply concerned in regard to the double-acting steam engines, fitted as they were with the latest details, including centrifugal governors as well as the parallel motion, a device which had not been proven to Watt's satisfaction until late in 1785. Moreover, the Albion Mill engines were of the then large cylinder size (for double-acting engines) of 34in bore by 96in stroke. The strong protest made by Watt regarding the admission of strangers may have been the reason why Thomas Jefferson—when he visited the Albion Mill in or about March, 1786—was permitted to see it " only superficially " (letter to Charles Thomson, secretary of the Continental Congress).

The scheme for the Albion Flour Mill had taken shape during 1783, the driving force behind the undertaking being the perceptive and organising genius of Matthew Boulton. This was at the time of the introduction of Watt's rotative engine, which event had not been followed by encouragement (in the shape of orders) on the hoped-for scale. It, therefore, occurred to Boulton that " if he had but the opportunity of exhibiting the powers of the new engine in its best form, and in connection with the best machinery, the results would be so satisfactory and conclusive as to induce manufacturers generally to follow the example." An application made during 1784 for a charter of incorporation was refused, however, on account of vigorous opposition by millers and mealmen. The scheme then went forward on the basis of a partnership, the greater part of the capital being provided by Boulton out of his own resources ; Watt also putting up a considerable fraction of his. The Mill was ready to start, in the early part of 1786, and it cannot be a matter for surprise that much labour and many set-backs accompanied its inauguration. Boulton was present at the start-up and in writing to Watt declared his disappointment with the working of the

double-acting engine, going so far as to express the view that it would have been better to install single-acting engines. The Albion Mill, while it proved commercially unprofitable at the outset, had a profound influence on the employment of steam engines for mill driving. In this direction the enterprise of Boulton and Watt was more than justified, the mill providing an epoch-making example not only of the arrival of power units unaffected by conditions which put water mills and windmills out of action, but of millwright equipment in which wheels and shafting were made throughout of cast or wrought iron instead of being constructed, as formerly, from timber.

The Albion Mill was beginning to prove remunerative when, on the night of March 3, 1791, it was set on fire by incendiaries who omitted no step likely to make destruction certain. They cut off the water supply from the water storage ; fired the building in a plurality of places, and by starting the blaze when the tide was low, rendered it as difficult as possible to get water on to the flames. The records show that the mill was completely burnt out in a few hours and how, notwithstanding the offer of a reward for evidence leading to their apprehension, the miscreants who set the place on fire were never discovered. When the Albion Mill went up in flames no reconstruction was undertaken ; its site, together with ground in Holland Street, adjacent thereto, becoming the scene, from 1791 onwards, of the labours of John Rennie and his sons. This extended not only to the millwrighting and other mechanical engineering activities which had so far occupied Rennie, but to the civil engineering and consultative work on which he was to be primarily engaged for the remainder of his life. It must have been in Holland Street that Rennie dealt with the designs for the many and celebrated civil engineering works for which he is remembered. These comprised canals, harbour works, docks and bridges, including the original Waterloo Bridge, Southwark Bridge and the existing London Bridge. Rennie—as has been pointed out by Rankine—had given special attention to investigations connected with the strength of materials, and this was, indeed, the foundation of his skill and success as a constructor whether of buildings or of machinery. Throughout the ages men of talent have been at work devising forms of construction and selecting materials wherewith to create buildings satisfactory from both the æsthetic and the functional standpoints. The bulk of the credit for these buildings goes to architects notwithstanding that the Greek root—*arkhitekton*—of this word signifies not an artist, but rather a builder. Engineers and architects have, on occasions, expressed candid views about each other, as when James Watt commented acidly on certain changes proposed by an architect dealing with Handsworth Church. "If," he said, "these changes are made, preaching in Handsworth Church will be like squirting the word of God through a keyhole." It is fortunate that there have always been men so gifted as to combine, as did John Rennie, the skill of the constructor with the deep sense of proportion and harmony which we have come to associate with the architect.

After Rennie's death in 1821 the mechanical engineering work carried out at Holland Street was supervised by his son George. It included much more than the millwrighting which, at the outset, had brought the name of Rennie into prominence. We read, for example, that from Holland Street Works there came the first special machinery for the quantity production of biscuits. Here, also, was built the propelling machinery for the "Archimedes," in which Sir Francis Pettit Smith's screw propeller was tried out. Later (in 1840) George Rennie constructed the machinery for H.M.S. "Dwarf," the first vessel in the British Navy to be propelled by screw. John Rennie Jr. (later Sir John) carried on the civil engineering section of the partnership, and among other undertakings he superintended the construction of London Bridge for which the designs had been made by his father. On the opening of the bridge during 1831, the younger John Rennie received a knighthood, being the first member of the engineering profession so honoured since King James I conferred a knighthood on Hugh Myddleton. Both Sir John Rennie and his celebrated father were Fellows of the Royal Society.

John Rennie resided in the immediate vicinity of Blackfriars Bridge from the time of his arrival in London—at the end of 1784—until his death in 1821. At the outset he appears to have lived in what was then Great Surrey Street. Later, and probably about 1790, he moved to the house on the north side of Stamford Street wherein he died on October 4, 1821. This house stood at the west corner of Bennett Street (since renamed Rennie Street), and it was here that Rennie received (among other distinguished visitors) his old friend and teacher Professor Robison, who is known to have stayed with him for some time during 1793. This was while Robison was working on scientific articles for the *Encyclopædia Britannica*, though a further topic for discussion with Rennie would certainly have been the litigation then pending on the subject of Watt's patent No. 913. Robison was among Watt's lifelong friends and the case of Boulton and Watt *v.* Bull came on for hearing in the Court of Common Pleas on June 22, 1793. The records further show that it was in Stamford Street that Rennie's second son (the future Sir John Rennie) was born during 1794. The house was demolished some years ago, its site being now covered by the warehouse and lorry loading station belonging to a large provision business. A plaque on the wall facing Stamford Street commemorates the residence and death here of John Rennie and the birth—in an adjoining house which has also disappeared—of John Leech the caricaturist. The house on the south side of Stamford Street opposite the site of Rennie's house appears to have been built about the end of the eighteenth century and would be an object specially familiar to him. Also familiar would be the chapel and many of the houses still remaining in Stamford Street. Rennie Street runs southward from the Bankside thoroughfare known as Upper Ground to the churchyard of Christ Church, Blackfriars, the church here having been almost completely obliterated during the bombing of the second world war. Christ Church, Blackfriars—built about 1740—would be well known to Rennie as must also have been the nearby Running Horse Yard, then a coaching station. In going from his house in Stamford Street to his drawing-office and works, Rennie had little more to do than cross Blackfriars Road into Holland Street. That he died at the comparatively early age of sixty years and four months was due, it is believed, to the excessive and constant demands he made on his strength. One who knew him has recorded Rennie's capacity for work in the following words :—

"Work was with him not only a pleasure—it was almost a passion. He sometimes made business appointments at as early an hour as five in the morning and would continue incessantly occupied until late at night."

His last business letter was written on September 28, 1821, six days before he died.

Were John Rennie to visit the Blackfriars Road to-day he could find but little left—apart from Hopton's Alms Houses and some domestic buildings—of the structures which stood here in his time. He would, however, be greatly exercised by the impressive Bankside Generating Station of the Central Electricity Generating Board and the towering headquarters building of the United Africa Company, the latter of which stands close to the site of the house in Stamford Street wherein he lived and died. Perhaps nothing would exercise him more than the passage of helicopters to the nearby helicopter port. We may wonder what Rennie—whose skill as an engineer was matched by his singular architectural taste—might have thought of the hideous railway bridge which, throughout nearly a century past, has marred—for the pedestrian crossing Blackfriars Bridge to the north bank—the view of St. Paul's Cathedral. He would also have been astonished that the attic storey, roof and towers of the Faraday Building in Queen Victoria Street should, at a much later date, have been allowed to impair one of the most magnificent architectural vistas in the world. Looking at Wren's great dome we shall remember that John Rennie is among the illustrious dead buried in the crypt below it. While the name of Rennie is commemorated by the street so called and by the name of the Bankside wharf adjacent (on the east) to Blackfriars Bridge, it would surely be appropriate if some suitably inscribed plaque could be set up on the site of his works, a memorial which, visible to the passer-by, would also commemorate the Albion Mill and its epoch-making equipment. The bi-centenary of Rennie's birth occurs on June 7, 1961, a date which would provide a singularly felicitous occasion for the unveiling of an inscription.

Looking from Bankside across the Thames we can see the obelisk known as Cleopatra's Needle. It seems odd that an Egyptian (Thothmes III) who lived about 3500 years ago should be commemorated with such magnificence, while just across the river there is nothing to indicate the site of an installation which may be said to have marked the commencement of the momentous era of steam-driven mills. Surely it is time some memorial was erected recording the position of this mill and commemorating those who designed, erected and set to work its epoch-making machinery.

### Stereophonic Broadcasting System

A NEW system for stereophonic transmission of sound broadcasts has just been put forward to the European Broadcasting Union for assessment. This is a time-multiplex system and has been developed by G. D. Browne, of the Research Laboratories of Mullard, Ltd., Mullard House, Torrington Place, London, W.C.1. It is stated that receivers for this system would only need the addition (apart from the second loudspeaker and audio stage required for stereophony) of at the most two valves or possibly one transistor and two diodes. Existing v.h.f. radiograms with stereophonic record reproduction facilities would be convertible in many cases to receiving stereo broadcasts on the Mullard system by the addition of a valve and associated circuit. The proposed stereo transmission system is compatible, and unconverted v.h.f. sets would therefore be able to receive the transmissions and reproduce them in the normal way.

# SHORTER REPORTS

## Radio Trades Examination Board

IN its report for the year ended August 31, 1959, the Radio Trades Examination Board, 9, Bedford Square, London, W.C.1, states that its technical courses in radio, television and electronic servicing met with considerable success—measured in terms of the number of candidates entering for the examinations. In 1959 a total of 2310 candidates sat the radio and television servicing examinations, representing an increase of 33 per cent on the number sitting in 1958. Unfortunately, this larger number of candidates did not provide the same increase in the number of successes, and in fact in the radio servicing examination there was a drop in the number of candidates qualifying for a certificate. Out of 1847 candidates last year, there were 547 passes, as compared with 622 passes out of 1498 candidates in 1958, the percentage pass being 30 per cent, compared with 42 per cent the year before. In television servicing, however, 209 candidates passed out of 463 entries, as against 119 passes and 314 entries in the previous year, the percentage passes being 45 per cent and 38 per cent respectively.

The relatively poor results in the radio servicing examination have been the cause of much discussion. Written papers were very much below the normal standard and were the main cause of failure, and this inability to cope with theory undoubtedly resulted in many candidates failing the practical examination. The present syllabuses for radio and television servicing have been in operation virtually unchanged since the examinations were first set, and during the year a complete revision of the two syllabuses took place. Apart from revising the material itself, an opportunity was taken to combine and weld together the radio and television subject matter throughout the syllabus. Thus, the board will now provide an intermediate examination in radio and television servicing at the end of the third year of the part-time course and a final examination in radio and television servicing at the end of the fifth year.

The scheme for candidates engaged on servicing, installation and maintenance of electronic equipment has now moved a stage further and a syllabus is at present in the final stages of approval. It is arranged so that the syllabus for the first two years is common with that of radio and television servicing. Separate intermediate and final examinations in electronics are to be held. An increasing number of technical colleges is anxious to embrace this scheme of examination, the first of which will be held at the intermediate level in 1961.

## "Human Engineering" and the Control of Nuclear Stations

SPECIALIST American experience in the comparatively new field of ergonomics or "human engineering" is to be shared with the Atomic Energy Division of The General Electric Company, Ltd., of England. A three-man team of experts from Dunlap and Associates, Inc., of Stamford, Connecticut, arrived at the Atomic Energy headquarters of G.E.C. in Erith on January 26 to undertake a human-engineering analysis relating to the central control room of a nuclear power station. The team, which is led by Jerome H. Ely, Ph.D., an assistant vice-president of the American company, will take four weeks to complete its work in England.

Human engineering is rapidly becoming accepted as an important approach to a variety of engineering design problems. Essentially, its objects are to ensure that new designs are compatible with known human limitations and capabilities; and that a machine, or system, and its operator should be so fitted to each other that they can work together to give the best possible results.

In the design of nuclear power stations, with their necessarily complex control systems, this approach can be of particular value. The application of human-engineering principles can do more than increase the operational efficiency of an installation. By ensuring the effectiveness and the comfort of the operators, it can contribute to the safety of the plant. Because of the importance of these considerations, a section was established some time ago in the Atomic Energy Division of the G.E.C. to study their implications.

Although much research and development work has been done in this field in the last decade in the United Kingdom, the U.S.A. has far greater experience of its application in industry. Dunlap and Associates, Inc., have done this kind of work for many leading American industrial organisations and for a number of government departments. Apart from the immediate contribution which the American team's survey will make to G.E.C. nuclear designs, the British company will gain by the acquisition of American experience and "know-how" in applying human engineering.

## "TRIGA" Nuclear Reactors

A LICENCE agreement has been signed to enable Vickers-Armstrongs, Ltd., Broadway, Westminster, London, S.W.1, to manufacture and sell in the United Kingdom "TRIGA" atomic reactors which have been developed by the General Atomics Division of the General Dynamics Corporation, San Diego, California.

The reactors covered by this agreement are designed for training, research and isotope production and for medical and industrial applications. They have an exceptional measure of inherent safety because they embody homogeneous fuel moderator elements of uranium-zirconium hydroxide: the homogeneous mixture of uranium fuel and zirconium hydride moderator provides a prompt negative temperature coefficient which acts as an automatic and rapid self regulating mechanism to prevent the core from overheating in the event of a power excursion. With this rapid self-regulating characteristic "TRIGA" reactors can be used for "flashing"—providing very high power levels for very short periods—a procedure which may have applications in the biological field, for example. Neutron flux densities of $10^{16}$ to $10^{17}$ have been achieved momentarily when "flashing" the prototype "TRIGA" by increasing its power output from 1W to 1500MW thermal, (more than six decades) in less than 0·1 second.

The average thermal neutron flux in the core at 100kW is $1{\cdot}6\times10^{12}$n/cm²/sec. The critical mass is 2 kg, and the active lattice is 17in diameter by 14in high. Each fuel moderator element is contained in an aluminium tube about 28in long, with a wall thickness of 0·03in. The composition of the fuel-moderator material is, by weight, 8 per cent uranium, 91 per cent zirconium, 1 per cent hydrogen, the uranium enrichment being 20 per cent $^{235}$U.

Two versions of the reactor are involved in the present agreement. In the first, the below-ground "TRIGA" Mark I, the reactor core is at the bottom of a 21ft-deep cylindrical tank which is in a concrete lined pit. Shielding is provided by the surrounding earth and, vertically, by a depth of 16ft of demineralised water which also cools the core by natural convection. No containment building is required. The reflector is an aluminium clad graphite cylinder enclosing the core. Irradiation experiments can be carried out in a forty-position rotary specimen rack (with a pneumatic transfer tube) where the thermal neutron flux is $0{\cdot}7\times10^{12}$n/cm²/sec., and in a central thimble where the flux is $4\times10^{12}$n/cm²/sec.

The "TRIGA" Mark II reactor is built wholly above ground and combines a thermal column and beam tubes with large scale irradiation facilities adapted for research in universities and other institutions. Radial shielding is provided by 7ft 6in of ordinary concrete. In addition to the irradiation arrangements of the Mark I reactor the Mark II version has a graphite thermal column 4ft by 4ft by 5ft 6in, extending from the reflector through the concrete shielding, to offer a source of well thermalised neutrons suitable for physical or biological irradiation experiments. A rolling door, 3ft 6in thick, shields the outer face of the column and a removable 6in concrete plug in the rolling door gives easy access to the central stringer.

The Mark II reactor also has four 6in diameter horizontal beam ports through the shielding, to give access to neutrons or gamma rays for a variety of experiments. Two of the beam tubes extend radially to the reflector face. A third tube, also radial, penetrates the reflector to the face of the core, and provides a higher flux. The fourth beam tube is tangential.

Diametrically opposite the thermal column there is a bulk shielding tank, giving access to neutrons for shielding experiments and tests on materials in a pool 9ft long by 8ft wide by 12ft deep.

Among the interesting applications of "TRIGA" reactors in research are those of activation analysis in agriculture, medicine and research. In agriculture, activation analysis can be used to study the influence of trace elements on plant life and the ionising flux can be used to induce mutations and develop new and resistant strains. In medicine, activation analysis can be used to determine trace elements in body tissues, and to detect minute chemical changes in diseased body cells. In metallurgy and engineering, materials can be activated for studies of leakage, wear and segregation.

"TRIGA" is well suited for the production of isotopes, particularly short-lived isotopes for research or industrial use. It can produce, for example, $^{24}$Na, $^{42}$K, $^{38}$Cl, and $^{64}$Cu for use in measuring uptake, distribution and concentration of compounds in plants. These isotopes as well as $^{82}$Br and $^{128}$I are widely used in medical diagnosis and therapy. In engineering, $^{24}$Na and $^{38}$Cl are useful in hydrodynamics research and mass-transfer experiments. "TRIGA" can generate both long-lived and short-lived isotopes for experimental work on absorption, porosity and detergency.

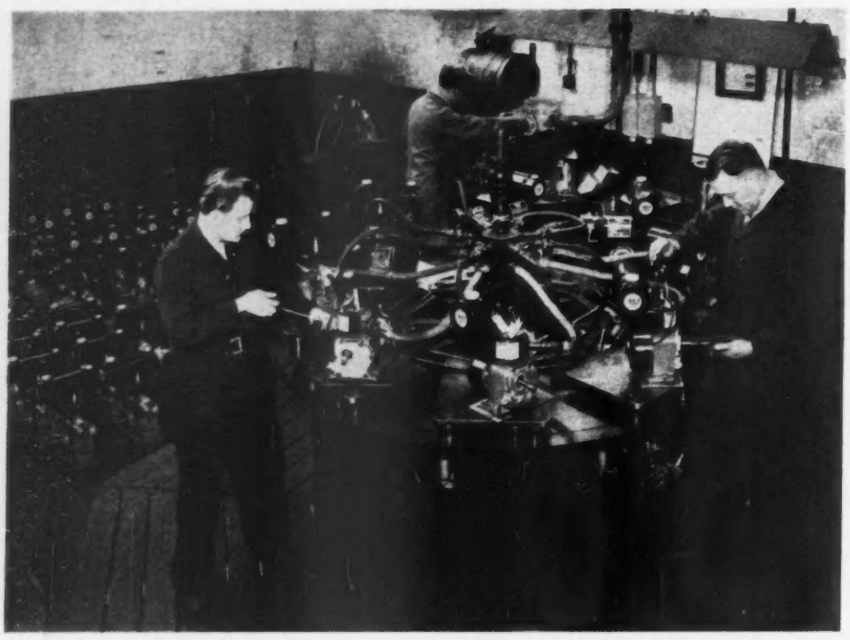
Four "TRIGA" reactors made by General Atomic Division of the General Dynamics Corporation are already in operation, and ten others are under construction in Austria, Brazil, Italy, India, Japan, Viet Nam and the U.S.A.

## Industrial Petrol Engines

A RANGE of 87 c.c. single-cylinder, four-stroke power units dimensionally interchangeable with engines of United States origin has been introduced by the Power Unit Division of B.S.A. Motor Cycles, Ltd. Production is at present diverted to overseas markets, but small quantities for prototypes are available in Great Britain. The engine is utterly distinct from any motor-cycle design, being largely of cast iron and having a flywheel magneto but no oil pump: although the engine is normally limited to 3600 r.p.m. (60 c/s), unusually great efforts have been made to reduce reciprocating masses, the design incorporating a connecting rod of aluminium alloy (running direct on the crank) and side valves. The output at full throttle is a virtually constant 2¼ lb-ft (80 lb per square inch brake mean effective pressure) from 2000 r.p.m. to 3600 r.p.m. (at sea level, 60 deg. Fah.).

Three versions of the engine are available, the 90B, 90C and 90V. The 90B is an orthodox

# SHORTER REPORTS *(Continued)*



**Three 90C engines can be recognised on this rotary eight-station test bed. The dynamometer station is behind the operator who is setting a governor. The four engines at the far side are larger models with horizontal carburettors and are, it will be observed, running on gas**

vertical engine, but employs plain bearings throughout. The 90C has the drive side crankcase end cover flanged, spigoted and threaded for close coupling to pumps, generators and so on, and a ball main bearing fitted in it. The 90V has the crankshaft vertical with the drive end downward, and another different end cover forms the sump : whereas the other models are entirely splash-lubricated, the 90V has a screw feeding oil up through the hollow camshaft to the timing side main bearing. The three designs all have different drive shaft terminations.

Distinctive features of these engines are that the governor senses the flow of the cooling, not combustion, air, and that the ignition is cut out by earthing the high, not low, tension side.

*Engine Data*

| | |
|---|---|
| Bore | 54mm |
| Stroke | 38mm |
| Maximum output | 1·9 b.h.p. at 3600 r.p.m. |
| Continuous output | 1·6 b.h.p. at 3600 r.p.m. |
| Weight | 23¼ lb |
| Fuel tank capacity | 1½ pints |
| Oil sump capacity | ¼ pint |
| Starting | Pulley and cord |

Extras available include enlarged fuel tank and rewind starter.

[Reply Card No. E1914]

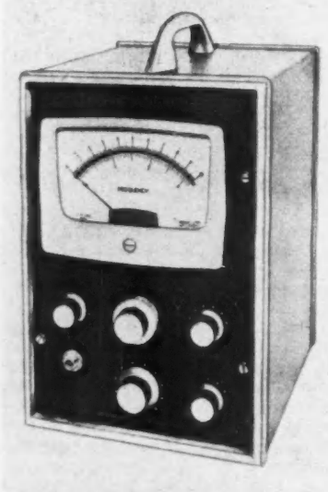
## Transistorised Analogue Frequency Meter

CONTINUOUS monitoring of a current proportional to the frequency being measured is the principle of a new frequency meter, TSA501, developed by Venner Electronics, Ltd., Kingston By-pass, New Malden, Surrey. Accuracy is largely independent of the input waveform, since the input circuits of the meter shape the incoming wave to a particular pulse form. The pulses switch a binary stage by means of which a capacitor is connected alternately to a zener-stabilised voltage source, and to a meter calibrated in frequency. The rate of charging the capacitor, and hence the current in discharge periods, is governed by the input frequency and the circuit time constant.

The instrument employs transistors throughout and measures 10in by 7in by 8in. A range of 3 c/s to 300 kc/s is covered in ten steps, each of which is capable of expansion by 3 or by 10 to facilitate differential measurements. Extra damping of the meter by a $\times 10$ or $\times 100$ time constant is available on the lower frequency ranges. Full-scale deflections on the ten ranges are 10 c/s, 30 c/s, 100 c/s, 300 c/s, 1 kc/s, 3 kc/s, 10 kc/s, 30 kc/s, 100 kc/s and 300 kc/s. The input voltage of the frequency to be measured may be from 200mV to 250V r.m.s. for sine waves or from 0·5V to 250V peak for pulse waveforms. The meter may be operated from two internal 6V batteries, an external 12V battery, or from mains of 100–125V or 200–250V, 50 c/s. Consumption is 70mA.

Used in conjunction with a Venner TS22 combined photohead and light source, the instrument will measure the speed of a rotating shaft or wheel. A socket at the rear provides the necessary power supply and signal lines to the TS22 unit. A remote indicator or recorder may be connected to the frequency meter through a further rear socket.

[Reply Card No. E1921]



**Portable meter for frequency measurement by voltage analogue**

## Modified Type 2 Locomotives

DARLINGTON (North Road) locomotive works of the North-Eastern Region, British Railways, has completed the first of a new series of twenty Type 2 $B_0$–$B_0$ 1160 h.p. diesel-electric locomotives of the " 5000 " series. These are the first diesel-electric locomotives built at Darlington, and give practical expression to the policy of maintaining locomotive building under the modernisation plan in an area hitherto actively engaged in steam locomotive construction. The new series incorporates certain modifications directed to saving weight compared with the earlier batches built at Derby and Crewe, and described in our August 1, 1958, issue. Weight in working order is still quoted as 75 tons, as specified before, but we understand that the figure has been exceeded in earlier production. Re-design of mechanical details includes a more extensive use of light alloys and of lighter sections throughout. Further weight has been saved in the engine-generator set by dispensing with the separate exciter for the main generator, and by using thinner steel plates in the Sulzer 6LDA28 diesel engine.

The main contract for the power equipment was placed with the British Thomson-Houston Company, Ltd., whose traction interests are now amalgamated with the Traction Division of Associated Electrical Industries, Ltd. In previous Type 2 and Type 1 locomotives equipped by B.T.H. the main generator separate field excitation has been supplied by a belt-driven exciter having a separately-excited field controlled by the automatic load regulator. In the new locomotives the separately-excited field of the main generator is fed from the auxiliary supply via the load regulator, and there is a compensating self-excited field carrying the main traction current to limit the excitation and obtain a characteristic similar to that given by the previous exciter system. The diesel engines are being built to Sulzer design by the licensee in Great Britain, Vickers-Armstrongs, Ltd., at Barrow-in-Furness.

These locomotives have been designed to the requirements of the British Transport Commission under the general direction of Messrs. J. F. Harrison, Chief Mechanical Engineer, and S. B. Warder, Chief Electrical Engineer, British Railways Central Staff, British Transport Commission ; the supervision of construction is the responsibility of Mr. M. G. Burrows, Chief Mechanical and Electrical Engineer, North Eastern Region, British Railways (York), and the work has been carried out under the immediate supervision of Mr. J. S. Scott, the Works Manager.

[Reply Card No. E1922]

### Congress on Large Dams

THE seventh congress of the International Commission on Large Dams of the World Power Conference is to be held at Rome from June 26 to July 2, 1961. The congress will be followed, as is customary, by several alternative study tours. The following are the " questions " which will comprise the technical programme of the seventh international congress :

*Question No.* 24.—The selection, processing and specification of aggregates for concrete for large dams.

*Question No.* 25.—Underground work in connection with large dams.

*Question No.* 26.—Modern techniques of concrete dams for wide valleys and ancillary works.

*Question No.* 27.—Sealing of earth and rockfill dams with bitumen and other materials.

## Electric Road Transport

THE winter meeting of the Canadian Electrical Association at Quebec on January 26 heard a paper entitled "Electric Road Transport—The Promising Present and the Challenge of the Future," presented by Mr. H. W. Heyman, B.Sc., M.I.E.E., managing director of Smith's Delivery Vehicles, Ltd., of Gateshead-on-Tyne, and a director of Smith's Electric Vehicles of Canada, Ltd. In his account of "the promising present," Mr. Heyman quoted figures of electric road vehicles licensed in the United Kingdom (excluding Northern Ireland) from 1938 to 1958, drawing attention to the spectacular rise in recent years. The number in 1938 was 4156, while in 1958 it was 35,917, or over four times the number of registrations at the end of the war. With any traction battery at present available, however, electric vehicles were limited in range and speed. Even with the new lightweight batteries, the distance which could be travelled per charge, and with a useful payload, did not normally exceed 40–60 miles, at a speed of not more than 20–25 m.p.h. There was also the need for a period of 12–14 hours off the road for recharging (normally during the night). This meant that, at present, electric vehicles lacked the flexibility normally expected from a passenger car and, among commercial applications, were confined to those which called for regular transport over a predetermined route, such as house-to-house delivery and collection. Users found that in town the prompt acceleration after stops and in traffic tended to counteract the relatively low top speeds. Municipalities also used electrics for refuse collection, street cleaning, tower wagons, and so on.

The author then considered the first cost and fuel cost of battery vehicles. At present, despite its simplicity and small number of parts, a battery electric chassis was not cheaper than an equivalent chassis with internal combustion engine because the present potential market for electric vehicles did not permit large-scale production. At the same time, the economic life of the electric was probably twice as long, so that the cost of depreciation—to which must be added spare parts, repairs and maintenance (reduced to a minimum on an electric chassis) should work out at about half. With regard to fuel costs, the battery should be regarded as "fuel purchased in advance." It was thus a consumable item and the cost of battery replacement every four years should be included in the cost of fuel. Charging current had also to be considered, and on this basis the author calculated the total fuel cost per mile for a 1½-ton dairy truck, carrying 600 quarts of milk a day and covering a 30-mile route six days a week, as 6·9 cents per mile. A petrol vehicle on similar service, with frequent starting and stopping, would have a fuel cost of approximately 8 cents per mile. With fuel costs about the same, the author claimed, the electric vehicle was bound to be more economic than any other form of transport, since all other expenses were very much less.

Still on the subject of "the promising present," the author mentioned an alternative to resistance control for which United Kingdom patents are pending. This was based on the use of solid state thyratrons in the form of silicon controlled rectifiers. A number of these would be connected in parallel to control the starting current of an electric road vehicle. Instead of gradually increasing the voltage applied to the traction motor, as with conventional resistance control, a transistorised variable-frequency pulse generator would trigger and shut off the silicon diodes, and infinite, loss-free speed variation would be obtained by accurately controlling current impulses flowing from the battery to the motor.

Another new development was the "Servalco" printed circuit motor invented by Messrs. F. H. Raymon and J. Henry-Baudot, which was claimed to be ideally suited for power transistor control. The armature consisted of a glass or other ceramic disc, on each side of which flat ribbon-like copper armature conductors were produced by an etching process. The disc, mounted on the armature shaft, revolved in a planar air gap with the magnetic circuit excited by several permanent magnets. A separate commutator was unnecessary, the brushes riding directly on the bare surface of the armature conductors. The motor had a relatively large diameter in proportion to its length, and could be designed for slow-speed operation, being then mounted in the wheels of the vehicle and permitting a much simplified transmission. Motors would be operated in parallel to retain differential drive between the two rear wheels.

The author described as "spectacular" the progress represented by the latest "Gauntlet" plate construction of Exide "Ironclad" traction batteries, incorporating sleeves woven in Terylene which enable the electrolyte to penetrate to the active material more freely than before, while reducing to negligible proportions the shedding of active material and lowering the internal resistance of the battery. The saving in weight with this new construction was appreciable, and the author quoted figures showing how the payload of a typical 1½-ton dairy truck could go up by 22½ per cent.

In his concluding remarks on "the challenge of the future," the author paid particular attention to the possibilities of the Bacon hydrogen-oxygen fuel cell and others using hydrogen or propane. Experts estimated that fuel cells for special applications would use hydrogen and should be available within five to ten years. It was probable that a considerable measure of further development would then be necessary before the fuel cell became sufficiently small, and at the same time powerful, to produce the revolution in transport which its emergence foreshadowed.

## Lubricant for Marine Reduction Gearing

THE most critical time in the operational life of marine reduction gear occurs during the initial running-in period, since, despite care in manufacture and installation, it is impossible to ensure contact over the whole tooth area. As a result, only a small part of the gear-tooth area carries the load and should this be too small a portion of the total possible area, local overloading may occur, and possibly leading to pitting and scuffing. Engineers have made an intensive study of the lubrication requirements of gears at the Thornton Research Centre of "Shell" Research, Ltd., and these investigations have led to the development of an oil for use with naval case-hardened gears. These require a lubricant of a higher load carrying capacity than is provided for in the specification of normal turbine oils and this new oil is now being used in merchant ships during the running-in period and acceptance trials. It has been found that this oil not only prevents damage during running-in but also assists the gears to be run-in more rapidly by means of its chemical polishing action. After the critical period is passed, then lubrication can be continued using normal turbine oils.

[Reply Card No. E1932]

## Unusual Repair of "Live" Sewers

SOME 650ft of old, leaky 9in stoneware sewer serving the Berkshire village of Donnington, near Newbury, was recently repaired while still in full operation. The method used was to drive 6in pitch fibre pipe through the old 9in sewer. By adopting this unusual procedure a saving in cost of about 50 per cent over the original estimated cost of the work is claimed.

The 9in stoneware pipes discharged into an underground pump house, adjacent to a river, and were laid approximately 8ft deep in a narrow, fully built-up village street. The pumps were grossly overloaded by infiltration of ground water into the broken sewers. The duty and standby pumps, rated at 67 g.p.m. each against a total head of 40ft, could not deal with the flow which, with a population of 410 persons, should have been about 7 g.p.m. The consulting engineers, Howard Humphreys and Sons, and the contractor, H. N. Edwards and Partners, Ltd., were faced with the problem of excavating the whole length of the old sewers and of laying new pipes in difficult ground conditions and with consequent disorganisation of traffic through the village. The method which seemed to give the best prospects was that of inserting 6in pitch fibre pipe inside the old 9in stoneware, and cement-pressure-grouting the space between them.

It was, of course, necessary to open up at every junction so that the 6in pipe could be connected to houses, &c. It was intended to push the pitch fibre pipes through from one excavation to the next. Although this was generally successful it was found difficult in some cases due to an accummulation of silt in the old stoneware pipes, and there were also some cases of settlement and projections on the inside of the old joints. When this occurred additional excavations were needed. The fibre pipes were driven with a sledge hammer (through the usual wooden block) and the maximum length successfully inserted in one operation was 90ft. The sections of the original drain which were opened up were made good with concrete and the annular space between the two pipes grouted. The benchings in the manholes were made good to suit the new pipes. On completion of the work the power consumed by the pumps dropped from an average of 65 units to approximately 10·6 units per day, and the night flow on the whole system was reduced to 3·5 g.p.m. The whole of the repair work to the sewer, which included junctions and branches, was carried out in twelve weeks, and the total length of pipe inserted was 218 yards. The pitch fibre pipe was manufactured by The Key Engineering Company, Ltd.

[Reply Card No. E1933]

## Electric Arc Steel Furnaces

IN our issue of December 11 last we announced the decision of The United Steel Companies, Ltd., to replace the twenty-one open-hearth furnaces at the Steel, Peech and Tozer works, at Rotherham, by six electric arc furnaces. It is expected that this substitution will be completed in five years' time. It has now been stated that the first two arc furnaces are to be supplied by G.W.B. Furnaces, Ltd., Dudley. These furnaces, each of which is rated at 40MVA, are to be of Demag design, although, apart from the regulator, they will be built in this country, the steel construction being undertaken by Distington Engineering Company, Ltd., a member of the United Steel group.

Each furnace shell will have an internal diameter of 24ft, a nominal capacity of 150 tons, and will be capable of melting at the rate of 1 ton per minute; in practice, the furnaces will be used for a maximum of 110 tons ingot weight. Construction of the furnaces will follow the Demag king pin or gantry design in which the roof is the only item lifted from the shell when the top charging takes place. The weight of the electrode equipment is permanently carried by the gantry which, after raising the roof, swings aside for furnace charging around a king post. Roof raising is by hydraulic cylinder and the gantry is swung aside by an a.c. motor and gear train. Shell and gantry are mounted on a platform supported by three arc-shaped rockers, which allow the furnace to tilt forward 45 deg. for pouring and 15 deg. backwards for slagging. The drive for tilting will be by d.c. motors through a gear train to pendant pin racks attached to the underside of the furnace. To facilitate the initial melt, shell rotation is incorporated and will allow the drilling of the scrap in three positions of each electrode. Rotation, which is 40 deg. either side the normal electrode position, is effected by an a.c. motor and gear train. Single-acting ram cylinders are utilised for positioning the electrode equipment and counter balance is provided by arranging the exhaust from the cylinders to be at a positive pressure. This counter balance pressure is variable and can be maintained quite accurately at the preset figure. Power for the arcs is to be provided by three-phase transformers, on-load tap changing being provided in a regulating transformer which feeds into a fixed ratio stepdown transformer. Both transformers are contained in the same tank and are forced oil cooled through external water-cooled heat exchangers. Two coolers each capable of dealing with the full load losses of the transformer are to be provided. The incoming supply will be 33,000V, three phase, 50 cycles, and the maximum arc voltage will be 565V.

[Reply Card No. E1934]

# SHORTER REPORTS *(Continued)*

## Extensible Oil Switch Units

EXTENSIBLE oil switches (type SX/A, air insulated ; and type SX/F, compound-filled) have been introduced by Johnson and Phillips, Ltd., Charlton, London, S.E.7, after tests at the K.E.M.A. laboratories in Holland.

The new oil switches are a development of the Johnson and Phillips NX non-extensible ring main unit. They are designed to line up with circuit-breaker units in composite switchboards for switching a ring main or spur feeder cable or to provide a safe means of isolating and earthing sections of cable and connected equipment, such as transformers or switchgear, for maintenance purposes. An SX unit incorporates all the features of one wing of the NX unit, rearranged to facilitate connection to continuous busbars and permit cable entry from the rear.

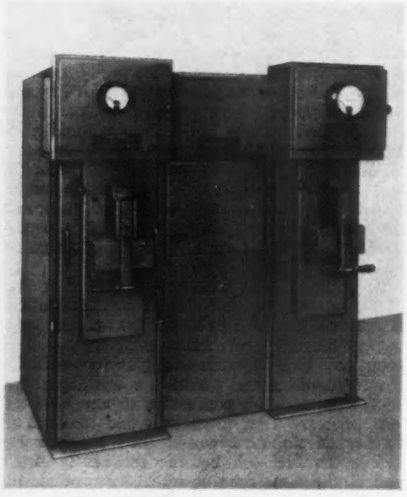
The SX/A and SX/F oil switch units are produced for inclusion in the company's AG (air-insulated) and FG (compound-filled) metal-clad switchboards. They have been designed for a normal rating of 400A and fully tested to B.S. 2631 for load breaking at 120A and 520A and for fault making on to the main and integral earth contacts. Certificates have been obtained at the K.E.M.A. laboratories for system fault capacities of 250MVA at 6·6kV, 250MVA at 11kV, and 350MVA at 11kV.

The units are the same width (1ft 9½in) as the breaker units and thus a circuit-breaker can be substituted for an oil switch without serious disturbance to the switchboard layout to suit a change in operating conditions.

The oil switches are fitted with manual spring-operated mechanisms which remove the dangers of hesitancy on the part of the operator when closing the switch. The switch contains a separate system of "signal arm" blades for "main" and "earth" connections, both "main" and "earth" blades being hinged on to a common cable box terminal. The individual blades are operated by separate shafts and insulating links, but one common spring is employed for the rotation of either shaft. This spring mechanism is so arranged that a foolproof interlock permits both "main" and "earth" blades of the switch to be open together, but only one or the other to be closed at one time.

The spring mechanism resembles that of the NX unit (described in THE ENGINEER, March 28, 1958, page 461) rearranged to suit the layout of the extensible switch. To open or close the switch the spring is charged by means of a removable handle which is placed over the top spigot and associated lever pin and then turned through approximately 45 deg. The lever pin will pass over-centre, and then, driven by the spring, will pick up the switch shaft driving plate and rotate it smartly, thus closing or opening the switch. The mechanism is designed to give an adequate operating force to the switch actuating shaft irrespective of the speed at which the operator charges the spring ; after initial compression, the spring takes the action of the switch completely out of the operator's control. The opening or closing of the earth blades is effected similarly, by applying the operating handle to the bottom spigot and associated lever pin.

**Extensible oil switch, type SX, for systems up to 250MVA at 6·6kV and 350MVA at 11kV**



**The "SX" extensible oil switch (centre) is designed to line up with circuit breakers, in composite boards, for switching a ring-main or spur feeder or for the safe isolation and earthing of cables and connected equipment in preparation for maintenance**

Each SX unit is made as a self-contained structure, the components being jigged for interchangeability. The busbars and oil switch are assembled in one structure and can be built into switchboards.

Means are provided for inserting cable testing plugs through the top cover of the unit, but access to the test orifices can only be made with the "earth" blades closed—which means that the "main" blades of the oil switch must be open. With the "earth" blades closed it is safe to connect cable test voltage leads to the test plugs and to open the "earth" just prior to applying the test voltage. Opening of the "earth" blades automatically traps the test plugs. These plugs cannot then be withdrawn from the test orifices until the "earth" blades of the oil switch are returned to the closed position.

There are other safety interlocks, their functions being as follows :

The "earth" blades of the oil switch cannot be closed whilst the "main" blades are in the closed position, and vice versa. Both sets of switch blades can be in the "open" position. Means are provided for padlocking the test cover to prevent unauthorised opening, and for locking the oil switches in their respective "open" or "closed" positions. Auxiliary switches can be provided on the rear of the unit to facilitate protection in certain system designs.

The standard Johnson and Phillips cable box has three gland positions to facilitate cable entry from any direction, but special cable box arrangements can be supplied. Epoxy resin or Bakelised paper bushings can be supplied as required.

[Reply Card No. E1941]

## Decimal Calculator

THIS aid to calculations covers five main functions : multiplication, division, fractions, percentages and banking interest. It consists of ninety-nine pre-calculated tables in card-index form and has recently been introduced into Britain by K. Miles, 13, Netherhall Gardens, London, N.W.3, from Switzerland. The tables can be adapted to an almost unlimited variety of calculations. Results are read at intersecting points of a horizontal and a vertical column, and are worked out, up to a certain stage, for all numbers from 1 to 9999. A special feature is the fractions which are very useful for technical calculations. It is claimed that this calculator gives complete accuracy in multiplication, which is practically unlimited, and any required number of decimal places in division. The divisor is limited to four digits.

[Reply Card No. E1942]

## Heat-Soak-Resistant Pivots

THERE has been evolved by Electro-Hydraulics, Ltd., a form of bearing adapted to use where the design cases are high strength with the bearing stationary in one attitude and resistance to heat in another. The particular application prompting this design was the undercarriage of an aircraft for supersonic cruise, in which at least the outer surfaces of the machine will be subjected to sustained high temperatures ; considerations of weight and structural integrity are expected to prevent the main structure being effectively insulated and cooled, and hence it becomes desirable to bar the heat from components, such as the undercarriage, which incorporate hydraulic systems, rubber and fibre parts, or even light alloys.

The principle of the temperature-tolerant pivot is illustrated below ; in (*a*) the configuration for load-carrying is depicted, the shaft *A* being loaded in the vertical direction and having flats *D* cut on the sides ; it is supported by the sectors *B* which are designed for high strength. At (*b*) the bearing has been rotated to the insulating attitude, and the shaft is now in contact only with the insulating material *C*.

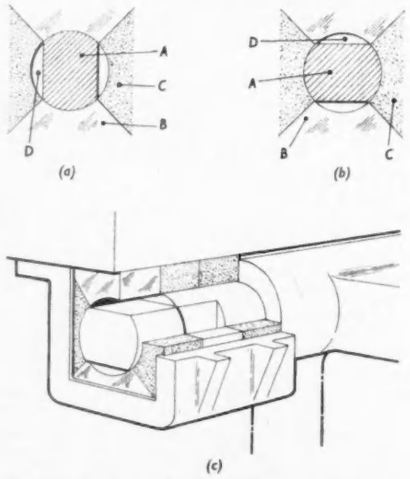



**Diagram illustrating principle of pivots designed to have high strength in one position and resistance to heating in another**

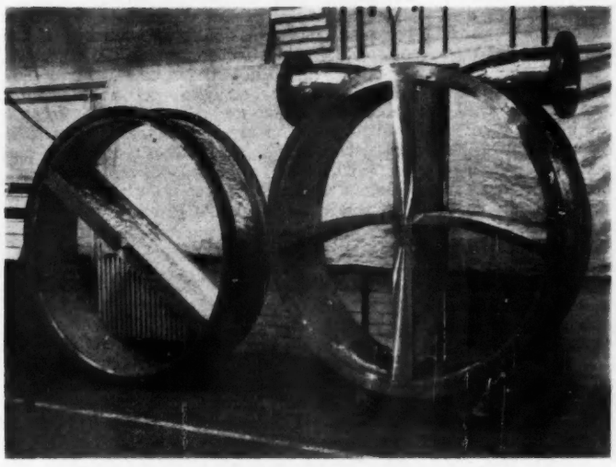
Even this simplest form of the bearing may be designed for loads in more than one direction ; in (*c*) it is seen how two of these pivots, 90 deg. out of phase, form a complete high-strength bearing at one end of the travel—in this case a third bearing, uniformly of insulating material, is provided so that the behaviour while rotating shall surpass that possible with the segmented housings. Clearly, where different ranges of travel are required different numbers of segments must be used ; travels of any odd number of sixths, eighths, tenths, twelfths, and so on, are available.

It is understood that no practical experience with this design has yet been acquired.

[Reply Card No. E1943]

## Aluminium Bronze Fabrication

OVER a period of time there has been close collaboration between N. C. Ashton, Ltd., the producers of aluminium bronze plate, sheet and castings, and W. P. Butterfield, Ltd., the fabricators of industrial plant, in an endeavour to solve problems related to fabrication of aluminium bronze. As a result of the association of the two companies, and their determination to overcome both major and minor difficulties in the welding of aluminium bronze, considerable success has been achieved, the tangible results of which we were able to see on a recent visit to the works of W. P. Butterfield, Ltd., at Shipley, Yorkshire. The results in question were fabricated water and return boxes for a large tubular heat exchanger for an oil refinery.



Water and return end boxes

It is mainly the addition of aluminium to copper which produces aluminium bronze, and there are a large number of alloys which range in tensile strength up to 50/60 tons per square inch. For a single phase solid solution alloy, the practical upper limit of the aluminium content is 8 per cent, the strength increasing progressively with the percentage of aluminium added. A typical single phase alloy is A.S.T.M. B.169 Alloy D, which contains 7·5 per cent aluminium and 2·5 per cent iron, and has an ultimate tensile strength of 35 tons per square inch and an elongation of 35 per cent on 2in. This particular alloy, which is ductile when cold, was used for these fabrications. When the percentage of aluminium exceeds 8, a duplex alloy is formed which is harder and stiffer than the single phase alloy, while the addition of other elements such as iron and nickel to the duplex alloys results in the formation of a nickel-iron-rich phase to produce complex alloys. A typical example of the latter alloys is A.S.T.M. B.171 Alloy E, which has as alloying elements 9·5 per cent aluminium, 3·5 per cent iron and 5 per cent nickel, and an ultimate tensile strength of 40 tons per square inch with an elongation of 10 per cent on 2in. The weld metal used for the fabrication work was Nartrode "E," which conforms chemically with B.171 Alloy E.

The tough continuous and self-sealing aluminium film on the surface of the aluminium bronze alloys makes them highly resistant to attack by sea-water, chlorides and dilute sulphuric and hydrochloric acids, so that they compare favourably with stainless steels in this respect. The material, due to its corrosion-resistant properties, has been used for pressure vessels, evaporators, and for heat exchanger parts which are subjected to sea-water attack on one surface and to attack by oil distillates, often acid bearing, on the other. The weldability of the aluminium bronzes is claimed to be comparable with similar materials, but, due to relatively high thermal conductivity and the formation of refractory oxides, a concentrated heat source and shielded weld pool are essential for successful welding of the material. Thus, the suitable processes are metal inert gas, tungsten inert gas and metal arc, and for the water and return box fabrications, shown in our illustration, inert gas metal arc welding was mainly used. Apart from the process, the composition of the weld metal is important to achieving a satisfactory weld. By reason of their excellent ductility properties when cold, the single phase alloys are readily produced in wire form. However, single phase alloys are susceptible to hot cracking, so that complex alloy wire which is reasonably free from cracking is better, although, due to the higher strength and lower cold ductility of the complex alloys, the wire is more difficult to produce. As already mentioned, the weld wire used for these fabrications was a homogeneous complex alloy containing nickel and iron and the metal deposited has an ultimate tensile strength of 43 tons per square inch and an elongation of 29 per cent.

The boxes consist of a ring formed of aluminium bronze plate rolled to a diameter of 5ft 10in and fitted with a web or webs and two mild steel flanges. The flanges are of 3in by 1½in mild steel section, have an outside diameter of 6ft 6in and are prepared for welding to the aluminium bronze assembly by cutting a weld groove in the inner edge and applying layer welding to its surface. Meanwhile, the aluminium bronze plate material has been prepared by shearing, friction band saw machining and by the tungsten arc cutting process as required. Two plates, each approximately 21⅛in wide by ⅜in thick, form the ring and are welded together before being rolled to the required diameter, when the final welds are made. The webs, built of ⅜in thick plate with 5in wide flanges, one of which is ⅜in thick and the other 1¼in thick, are tack welded together and then welded in position. The mild steel flanges, preheated to about 100 deg. Cent., are then welded to the aluminium bronze ring and finished with a multi-run back fillet weld. Welding of the webs follows, working from the centre outwards, and the final welds are those connecting the web flanges, which have a bevelled edge preparation, to the ring.

The opportunity was taken to make a tour of the works. Of particular interest was a composite fabrication in which there were thirteen examples of the welding of dissimilar metals, mainly by the argon arc process. Included were aluminium bronze welded to stainless steel, cupro-nickel, monel metal, mild steel and cast iron, and stainless steel welded to copper, carbon steel and cupro-nickel. Apart from the actual fabrication bays, part of the works is devoted to the complete fitting-out of road tankers with mechanical equipment and tanks built by the company.

[Reply Card No. E1951]

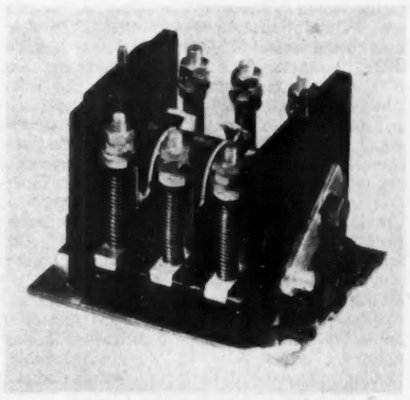
## Solid State Microwave Amplifiers

THE Institute of Physics announces that its Electronics Group, in conjunction with the Radio Spectroscopy Group, is arranging a conference on "Solid State Microwave Amplifiers," to take place at the University of Nottingham from April 6–8, 1960. The subjects to be covered by the conference include : (*a*) masers ; (*b*) parametric amplifiers ; and (*c*) related resonance studies. Accommodation will be available in one of the University Halls of Residence. Further particulars and application forms are available from the Secretary, The Institute of Physics, 47, Belgrave Square, London, S.W.1.

## Adjustable Auxiliary Switch

A NEW auxiliary switch with adjustable contact positions for linking mechanical movement with the associated electric control, protective, and alarm circuits, has been introduced by The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2.

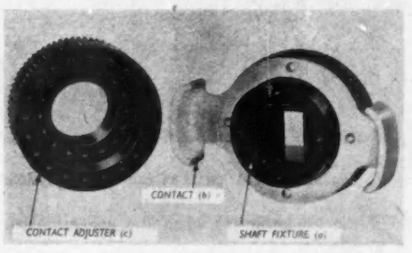
This switch, designated type SA, is of unit construction (as illustrated), and can be built up into composite assemblies for controlling up to twelve circuits. The contacts are silver-plated with a rating of 30A and are suitable for breaking d.c. inductive currents of 18A and 25A at 240V and 110V respectively.



"SA" auxiliary switch with contact position adjustable relatively to the operating shaft

Adjustments can be made to the angular position of each moving contact relative to the operating shaft by means of a simple vernier adjusting mechanism which forms an integral part of each moving contact assembly. This arrangement enables individual contact assemblies to be pre-set in any one of twenty-one effective positions, for a shaft rotation of 90 deg., and the timing of the make and/or break of the individual auxiliary circuits can be set accordingly.

As shown in the second illustration, each contact assembly consists of three parts—the shaft fixture, the contacts, and the contact adjuster. The shaft fixture (*a*) and the contact (*b*) each have four equally-spaced detents which engage respectively with an inner and outer circle of indents in the knurled contact adjuster (*c*). The inner circle has sixteen indents evenly spaced 22½ deg. apart, and the outer circle twenty indents evently spaced 18 deg. apart.




Adjustable contact assembly of "SA" auxiliary switch

By moving the contact adjuster and contact together one position, the contact is turned through 22½ deg. relative to the shaft fixture. Then, securing the adjuster and rotating the contacts back one notch (i.e. 18 deg.) results in a total change of 4½ deg. in contact position relative to the operating shaft.

A spring is provided to prevent the contacts being moved out of engagement involuntarily during adjustment, while a clamping screw at the end of the shaft firmly locks the moving contacts once they have been set in the required position. A transparent protective cover (not shown in the illustrations) is secured by two knurled nuts.

[Reply Card No. E1953]

# SHORTER REPORTS *(Continued)*

## Factory Fire Warning System

A COMPREHENSIVE fire warning system has been designed by Sound Diffusion (Auto-Thermic), Ltd., Portslade, Sussex, and installed in the works of Hoover, Ltd., Perivale, Middlesex. The installation at this works, the floor area being some 215,000 square feet, includes 2000 automatic heat sensitive detectors and fifty manual break-glass alarms at the exits. The detectors situated in each room, department and corridor are connected through an electric circuit and are designed to come into effect at a preset temperature and indicate the region of a fire on a central control panel to be seen in the accompanying illustration. For this particular installation the works has been divided into twenty-six sections, each section being represented by a pair of indicator lamps on the control panel. Under the practice adopted at the Hoover works the members of the full-time works fire brigade are alerted upon receipt of an alarm and as they proceed to the fire an alarm is given over the works loudspeaker system. The strength of the full-time fire brigade is supplemented by an auxiliary force of trained works volunteers who are directed to the fire automatic telephone dialling set, which operates with a pre-recorded message to summon the required assistance.

As already mentioned, the factory is divided up into twenty-six fire areas or sections, and at a strategic point in each of these sections there is installed a small "pulse box." A single cable wired in a ring circuit interconnects these boxes, the start and finish of this cable being brought back to the central control equipment. Into each of these pulse boxes is connected a local ring circuit in which are incorporated the detectors and manual pushes associated with the section served by the pulse box. Both the main ring circuit to the pulse boxes and the subsidiary rings to the detectors are monitored by a continuous current. Relays in each section pulse box are themselves held operated by a current flowing through their associated local co-axle cable loop, the power being derived from the main ring. On this twenty-six fire area installation there are thus twenty-six individual pulse boxes connected with the central equipment in a single ring.

When an alarm is originated in a fire area the relays in the associated pulse box release, and an alarm signal is passed via the main ring circuit to the central control equipment. The switching equipment in the central control unit then operates and sequentially counts around the pulse boxes on the ring until the pulse box on which the fire condition exists is located. A return signal is then given from this pulse box over the ring circuit and the central equipment gives a permanent indication of the relevant fire area. This indication is by the illumination of appropriate lamps on the main display panel of the central control equipment. Once the alarm condition in that fire area has been accepted the central equipment reverts to an "alert" condition, to locate any other outbreaks that may occur.

Central indicator panel of fire warning system at the Hoover works

over the loudspeakers when the general alarm is given.

Three kinds of automatic detectors are used in this installation and, according to their locations, are set to operate at temperatures varying from 120 deg. and 135 deg. Fah. One kind of detector used has a link of low melting point solder which fails under heat, another of break-link cable design having a tensioned conductor held by a connection of low melting point solder. The third form of detector has a circuit completed through bi-metallic strips which are actuated to break the connection by a rise in temperature. In certain parts of the factory detectors are compensated on a basis of rate of rise and maximum temperature to provide for seasonal temperature fluctuations.

In addition to the automatic alarm equipment the factory internal telephone system can be used to notify an outbreak of fire directly to the main control room by an employee dialling "6." It has been decided that the speed at which a fire can be detected with the new installation would enable an outbreak to be suppressed by conventional light-capacity factory hose and extinguisher equipment. If, however, an outbreak should be beyond the capacity of works equipment, the County Fire Service can be called by the control officer switching on an

In the event of a fire it is essential that the officer in charge at the control room should be kept aware of progress of operations by the fire-fighting groups. This can normally be done using the internal telephone system, but should this not be convenient a telephone can be plugged into a section box and direct communication maintained with the control room.

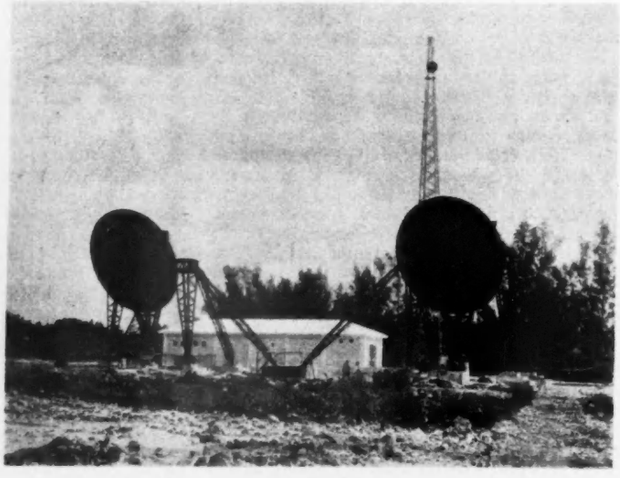
Power for the alarm equipment is provided by a bank of high-capacity nickel alkaline cells which are trickle-charged from the mains supply. The entire system is thus completely independent of the mains supply and should any component in the charger fail or the battery charging current fall outside the prescribed limits, an immediate fault alarm signal is given. A single push-button on the central alarm equipment enables the entire system to be completely tested in under ten seconds.

An advantage of this design of fire warning equipment is the flexibility afforded by the use of co-axial cables for connecting the detectors. These cables are not run in conduits and they can be quickly and easily clipped on to structural members or carried round obstructions. When it is required to change a production plant lay-out a section, together with its detectors, can be accordingly re-positioned without much difficulty or loss of time.

[Reply Card No. E1961]

## Tropospheric Scatter Terminal at Nassau

THE 186-mile over-the-horizon (O/H) 2000 Mc/s radio communications link between Florida City and Nassau in the Bahamas, to which we referred in our March 27, 1959, issue, began operation on January 17. We illustrate the forward scatter site at Nassau, showing the two 30ft diameter parabolic reflector antennæ facing Miami. These are common to the two 10kW transmitters and two dual-diversity receivers. In the background is the tower and antenna of the 7400 Mc/s line-of-sight microwave link which carries the baseband signal between the O/H terminal and the telecommunications centre in Nassau City, where multiplexing equipment is provided.



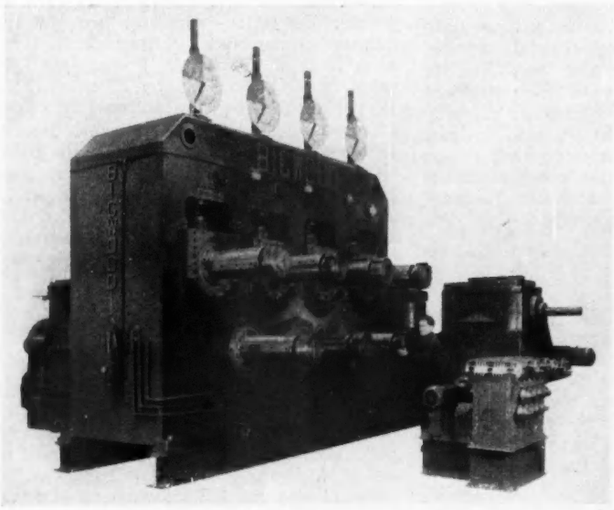
Nassau radio terminal, showing reflectors of the forward scatter system and tower of microwave link with Nassau City

Equipment for the Nassau terminal was engineered and manufactured by Standard Telephones and Cables, Ltd., Connaught House, Aldwych, London, W.C.2, which firm also supplied and installed the microwave link with Nassau City. The O/H terminal at Florida City was supplied by the Kellogg Switchboard and Supply Company of Chicago, Illinois, and I.T.T. Laboratories, Nutley, New Jersey, both S.T. and C. associates; and by U.S. divisions of the International Telephone and Telegraph Corporation. The system has a capacity of seventy-two trunk telephone circuits, of which twenty-four are scheduled for operation initially. Later the link will be supplemented in the Bahamas by an inter-island v.h.f. telephone network, also to be supplied and installed by Standard Telephones and Cables, Ltd.

[Reply Card No. E1962]

## Large Section Straightening Machine

THE accompanying illustration shows a large section straightening machine recently designed and built by Joshua Bigwood and Son, Ltd., of Wolverhampton, and delivered to the Indian Iron and Steel Company. This machine is capable of straightening rolled steel joists up to 18in by 6in, channels up to 17in by 4in, angles up to 8in by 8in by 1in, and flat bottom rails of up to 105 lb per yard weight.



Large section straightening machine with pass speeds of 100ft and 180ft per minute

The machine is built up from heavy steel weldments into which steel castings for the bearing housings are incorporated. All of its alloy steel roll shafts are mounted in massive roller bearings. A 150 h.p. motor, supplying the main drive for the bottom straightening rolls and the vertical spindle pinch rolls at the exit end of the machine, is directly coupled to a two-speed totally-enclosed reduction gearbox, giving pass speeds of 100ft and 180ft per minute. The top roll shafts are mounted in substantial chocks through which vertical and axial adjustments are made by geared motor drives. Large indicator dials at the top of the machine show the vertical settings of the top rolls.

Operation of the machine will be controlled from a conveniently situated desk on which there are mounted a reversing drum controller for the main motor and forward and reverse push-button starters for the vertical and axial top roll adjustment and for setting of the pinch roll. All the reduction and transmission gears are spray lubricated, whilst the roll shaft bearings run in oil and the other bearings are grease lubricated by a " Farval " equipment.

The other section straightening machine to be seen on the right of the large machine in the illustration is the smallest made by the company and offers an interesting contrast in sizes. Its maximum capacity is 1½in by 1½in by $\frac{7}{16}$in angles and 1½in by ⅜in flats.

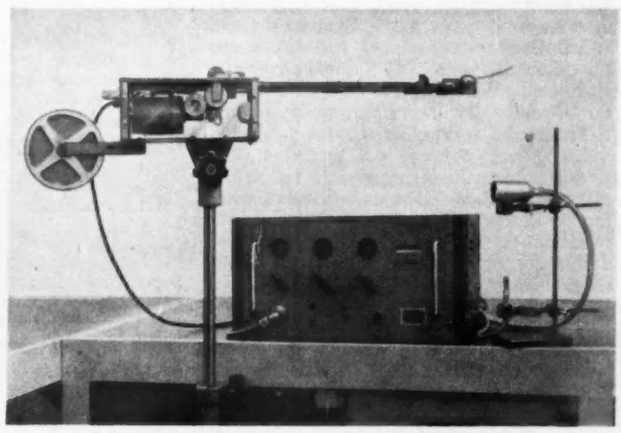
[Reply Card No. E1971]

## Electronic Control of Slip Inserter

THE standard " Batchcounter " of the Electronic Machine Company, Ltd., Mayday Road, Thornton Heath, Surrey, has been combined with a Soag slip inserter to provide a system for the automatic insertion of marker slips at preset intervals in piles of paper, board, tinplate, or other forms of sheet. In the accompanying illustration the light head and photocell which provide the input to the counter are seen on the right. These are fitted on the machine from which the output is to be counted at a position where a gap occurs between the sheets passing through. The required batch number is then set up on the " Batchcounter " by means of the three rotary switches, and each time this number is reached a pulse from the counter closes a relay which starts the fractional horsepower motor in the slip inserter. A friction drive from the motor feeds the strip of foil forward and operates a cam mechanism controlling a guillotine cutter and grippers at the end of the arm. After cutting, the slip is placed in position on the pile by the grippers. The progress of the count is indicated by the dekatron tubes on the " Batchcounter " and the cumulative total appears on a " cyclometer " form of display.

The installation works on a normal 200V/250V a.c. supply. The insertion arm is made in different lengths according to requirements and the height is adjustable between 3ft and 5ft 6in. It inserts a slip 4½in long by ⅞in wide at rates up to thirty per minute.

[Reply Card No. E1972]



Components of slip-inserting system, showing light head and photocell electronic counter, and insertion mechanism

## Non-Wetting Humidifier

To counteract the drying-out effects of central and other forms of heating, Aerosol-Turbo, Ltd., of 14, Cross Belgrave Street, Leeds, 2, has introduced its " Aerosolette," which is illustrated herewith, and which is a portable humidifier measuring 11in in diameter by 10½in high and weighing 10 lb. Lack of the correct amount of moisture in the air can affect health and cause physical damage to the contents of any space, but when a cold room is heated the relative humidity decreases automatically. To restore the correct relative humidity it is necessary to introduce additional moisture without, of course, producing wetting effects. This, it is claimed, is achieved by the " Aerosolette " non-wetting humidifier which is suitable for the average size room, and can disperse effectively germicides, insecticides, deodorants, &c. The machine effects complete atomisation of liquids into micro-aerosols, and the introduction of free air assists in their dispersal. The tiny particles have such a high surface tension that they are " dry " in effect. The " Aerosolette " emits about one pint of water per hour and consumes 60W.

Portable non-wetting humidifier

[Reply Card No. E1973]

## Power Hammers

WE are informed by B. and S. Massey, Ltd., Openshaw, Manchester, that drop forgers have in recent years shown an increasing interest in counterblow hammers originally designed by the firm some thirty years ago. As a result of this demand, the design of this type of machine has been completely revised to meet the severe conditions imposed by modern drop forging practices. The counterblow hammer has two vertically opposed tups, the lower one of which rises to meet the upper as the blow is struck. With this design the hammers are well suited for installation where ground conditions are unsuited to supporting the weight of a fixed anvil hammer and where ground vibration must be kept to a minimum.

These counterblow hammers are operated with steam or compressed air at 6/7 atmospheres and are made in ten sizes, covering a rated blow energy from 43,500ft-lb to 290,000ft-lb. A recently introduced improvement is a belt coupling compensating gear which ensures equal tension at all times in the belts that couple the top and bottom tups.

This firm's pneumatic power hammers are now fitted with a new design of foot-lever guard which is stated to be very effective in service. For use on its drop hammers, a range of nylon belts is now being marketed, and these belts are claimed to give a longer life and be superior in many ways to woven hair belting previously in general use. An improved form of friction brake and hold-up band lining is also being marketed for application on the company's design of self-contained and " Marathon " drop hammers.

[Reply Card No. E1974]

### Rocket Astronomy

A SMALL travelling exhibit on Rocket Astronomy has been lent to the Science Museum by the United States Naval Headquarters. Pictures showing the launching of rockets, photographs of the sun taken from the rockets, and an actual camera which has been recovered after use in a rocket are included in the exhibit, which is explained by a recorded talking commentary. The exhibit is open until the end of February.

# INDUSTRIAL NEWS

### Wages and Hours

The claim for a wage increase of £1 a week and a reduction of the working week to forty hours in the engineering industry was rejected for the second time on Tuesday at a meeting between the Engineering and Allied Employers National Federation and the Confederation of Shipbuilding and Engineering Unions. At the last meeting, on November 24, the employers had offered to reduce the working week to forty-two and a half hours, pointing out that that offer would have to be regarded as a full settlement of the claim. The unions were unwilling to accept this and earlier this month re-submitted their claim for a wage increase and a forty-hour week. On Tuesday, the employers' representative informed the unions that they could not agree to a wage increase but were prepared to concede a forty-two hour week. This was refused by the unions although they did agree to a meeting next week of a joint sub-committee which will examine the application of a forty-two hour week to piece rate workers.

Meanwhile, the Civil Engineering Construction Conciliation Board has announced this week that agreement has been reached for a forty-hour week to be worked in the four winter months, November to February inclusive. This agreement includes a compensatory wage increase of 1½d. an hour and an increase in overtime premiums from time-and-a-quarter to time-and-a-half for the first two hours of overtime. The unions had originally claimed a forty-hour week throughout the year without loss of pay, plus a wage increase of 4d. an hour.

### Steel Development Projects

The Iron and Steel Board has given its consent to a revised proposal by the Steel Company of Wales, Ltd., for its "fourth development plan" (THE ENGINEER, December 18, 1959) which will increase the steelmaking capacity of the Abbey Works at Port Talbot from 3,000,000 to 3,600,000 ingot tons a year and the company's production of sheet and tinplate by 400,000 tons a year. This consent has been given on the basis that arrangements will be made to enable large ore-carrying ships to be used. In response to a request from the Board, the company has decided to exclude from its present plan the hot strip mill. This should prove a more economical way of securing an adequate margin of productive capacity over likely demand, while avoiding the risk of creating an undue excess of hot strip mill capacity and of widespread underloading for some years of these large units of plant. It is stated that the change has been made possible as a result of an offer by Richard Thomas and Baldwins, Ltd., to roll slabs from the Abbey Works in the hot mill now under construction as part of its new Spencer Works, near Newport. The hot rolled steel coils will be returned to the Steel Company of Wales, Ltd., for conversion into steel sheets and tinplate. The agreement between the two companies will operate for a minimum period of five years. The capital cost of the Steel Company of Wales plan is thereby reduced from the original figure of £33,000,000 to approximately £20,000,000.

The Board has also given its consent to an extension by Colvilles, Ltd., of the original strip mill proposals which provided for 230,000 tons of sheet a year. The extension now agreed will raise the company's potential sheet production to 500,000 tons a year. The additional coke oven capacity which forms part of the extended proposals is the subject of consultation with the National Coal Board and others concerned.

### Overseas Trade

The Board of Trade has stated that the United Kingdom's exports last year were 5 per cent higher in value and 4 per cent greater in volume than in 1958. Between the two years, imports increased by 6½ per cent in value and in volume, but re-exports declined by 8 per cent owing to much smaller shipments of rubber to the U.S.S.R. last year.

The total value of engineering products exported grew by 3 per cent in 1958 and a further 6 per cent in 1959. But, the Board of Trade says, "the implied continuous increase was confined to a few categories of products." Exports of non-electrical machinery (excluding aero-engines) in total increased by 9 per cent in 1959, after a slight decrease in 1958. This category was sustained by a strong increase throughout the period in exports of agricultural tractors, the value of which rose from £65,000,000 in 1957 to £80,000,000 in 1959. Other kinds of machinery showing substantial increases between 1957 and 1959 included internal combustion engines, rising from £55,000,000 to £61,000,000, boilers and steam engines, from £25,500,000 to £27,000,000, and office machinery, from £19,000,000 to £21,500,000. Exports of excavating and earth-moving machinery showed a particularly strong recovery last year of 22 per cent, after a fall of 16 per cent in 1958. Exports of electrical machinery, apparatus and appliances were 4 per cent higher last year than in 1958. There was a considerable increase in exports of radio apparatus and valves but a fall in the value of exports of electric wires and cables, which was caused partly by the fall in the price of copper.

Exports of cars and chassis increased by 19 per cent in value in 1958 and in 1959. The growth in car exports to North America was sufficient to account for the increase in both years, Canada taking an increasing share, particularly towards the end of last year. Exports of commercial vehicles and chassis, which fell during 1958, rose again last year and regained the 1957 level, the main increase coming towards the end of the year.

### Shipbuilding Orders

The Shipbuilding Conference announces that during December, 1959, contracts for thirty-one ships of 122,000 tons gross were received, bringing the total of orders secured by British shipbuilders during the last quarter of the year to sixty-nine ships of 172,000 tons gross. This makes the total of orders received during 1959 198 ships of 319,000 tons gross, compared with the 1958 returns of 144 ships of 497,000 tons gross. The latest contracts brought the industry's order book at December 31, 1959, to a total of 498 ships of 4,169,000 tons gross, valued at £625 million, of which about 19 per cent is for foreign account. The corresponding figures at the same date in 1958 were 611 ships of 5,430,000 tons gross. Of the total tonnage on order, more than 2,000,000 tons have yet to be laid down, a figure which includes many ships, the construction of which has been postponed pending improvement in the shipping position.

### Unemployment

The Ministry of Labour reports an increase of nearly 40,000 in the number of unemployed in Great Britain between December 7 and January 11, the total registered as out of work on the latter date being 460,501 (336,572 men and 123,929 women). Of that number, 12,247 people were reported to be "temporarily stopped." It is stated that the January figure is 2·1 per cent of the estimated number of employees ; a year ago the figure was 2·8 per cent.

It is interesting to recall that the fiftieth anniversary of the opening of the national Employment Exchanges occurs on February 1. They were established in 1910, under the Labour Exchanges Act, 1909, which was introduced into Parliament by Sir Winston Churchill, who was then President of the Board of Trade. That Act gave the Board of Trade authority to set up exchanges for collecting and furnishing information about people seeking workmen and workmen seeking employment. Originally, the scheme provided for 250 exchanges ; to-day there are just over 900 exchanges and more than 100 sub-offices and branch employment offices. It is estimated that during the past fifty years, the exchanges have been responsible for filling over 100 million vacancies. The latest figures show that in the five-week period ended January 6, the exchanges filled 175,000 vacancies. The number of vacancies notified but remaining unfilled on January 6 was 245,000, which was 5000 fewer than in December.

### Engineering Production

The Board of Trade's latest statistics indicate that production in the engineering and electrical goods industries last October was slightly greater than in September and was 13 per cent higher than in October, 1958. Preliminary estimates for November show that production was higher than a year earlier, though the increase was less than in October. Orders on hand for engineering and electrical goods, mainly for capital goods, ceased to fall in the first quarter of last year and remained virtually unchanged until the end of October. The preliminary estimates for November indicate little change. The index of orders on hand (January, 1958=100) has been computed for November as 89 for export and 90 for the home market. That shows an upward movement of five points and one point respectively since April, 1958.

# PERSONAL AND BUSINESS

## Appointments

MR. J. F. NASH, A.M.I.E.E., has been appointed chief engineer of Auto Diesels, Ltd.

MR. J. L. STEANE has joined the staff of The Bronx Engineering Company, Ltd., as sales engineer.

MR. K. W. SIMS has been appointed export promotion manager of C. C. Wakefield and Co., Ltd.

MR. C. R. EVANS has joined Servomex Controls, Ltd., as manager of the chemical instruments division.

COMMANDER V. M. LAKE, R.N. (Rtd.), M.I.Mar.E., has joined the staff of Caird and Rayner, Ltd., as technical manager.

MR. CHARLES N. FREESTON, A.M.I.E.E., has been appointed group projects engineer for the Frederick Braby group of companies.

DOWTY GROUP, Ltd., has announced that Mr. Donald Campbell has been appointed managing director of Dowty Marine, Ltd.

MR. CURTIS M. KLAERNER has been appointed a director of Mobil Oil Company, Ltd., in place of Mr. Arthur L. Lanckton, who has resigned.

R. AND W. HAWTHORN, LESLIE (SHIPBUILDERS), Ltd., announces that Mr. R. Ibison has been appointed general manager in succession to Mr. C. Stephenson.

SIR HAROLD ROXBEE COX, M.I.Mech.E., has been appointed chairman of the National Council for Technological Awards, in succession to Lord Hives, who has retired.

POLYPENCO, Ltd., has announced the appointment of Mr. S. Sharp as its sales engineer for the north-eastern counties, comprising Yorkshire, Northumberland and Durham.

MR. ALAN J. MARLES, A.M.I.Mech.E., has been appointed technical manager of Ransome and Marles Bearing Company, Ltd., and will take up his new duties on February 1.

FERRANTI, Ltd., announces that Mr. W. D. H. Gregson, A.M.I.E.E., former London manager, has now taken up his post as assistant general manager of the company's Scottish group.

THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY announces that Mr. J. B. Laurie, M.I.E.E., has taken up the new appointment of general manager (commercial) at the production group headquarters, Risley.

BRYCE ELECTRIC CONSTRUCTION COMPANY, Ltd., announces that Mr. D. D. Hogg, A.M.I.E.E., has been appointed contracts manager. Mr. J. O. M. Palmer, A.M.I.E.E., has been appointed chief engineer.

MR. C. W. HAMILTON, managing director of McCall and Co. (Sheffield), Ltd., and McCalls Macalloy, Ltd., has been elected president of the Prestressed Concrete Development Group for the coming year.

THE BRITISH BROADCASTING CORPORATION has announced the appointment of Mr. W. L. Nicoll, A.M.I.E.E., as engineer-in-charge of the Kirk o' Shotts television and v.h.f. sound broadcasting station in succession to the late Mr. J. Cleland.

MR. W. H. WENTWORTH PING has been appointed general sales manager of Firth-Vickers Stainless Steels, Ltd. Mr. D. G. Gill-Davies has been appointed export sales manager, and Mr. D. W. Smith, assistant export sales manager.

PLENTY AND SON, Ltd., has announced the retirement of Mr. W. H. S. Aplin, after more than twenty years' service. Mr. J. F. Hall-Craggs, director in charge of the filter and chemical plant division, has been elected to fill the vacancy on the board.

MR. H. P. BARKER, M.I.Mech.E., M.I.E.E., chairman and managing director of Parkinson Cowan, Ltd., has been elected chairman designate of the British Institute of Management and will succeed Lord Verulam at the annual general meeting in October.

COCKBURNS, Ltd., states that Mr. L. W. Noble, formerly manager of North Shields branch works has been appointed manager, London office, and Mr. W. A. Duckworth has been appointed as manager of a new office which has been opened in Manchester.

BABCOCK AND WILCOX, Ltd., announces that Mr. A. S. Peacock, A.M.I.Mech.E., has been appointed purchasing controller with effect from February 1. Mr. J. S. Greenhalgh will relinquish his appointment as purchasing controller with effect from February 1, and will become manager, construction equipment division.

BRIGADIER H. P. CROSLAND, chairman and managing director of Metal Traders, Ltd., has been elected chairman of the Zinc Development Association for 1960. The former chairman, Mr. R. T. de Poix, will continue as a member of the Council of the Association.

BRITISH ENGINE, BOILER AND ELECTRICAL INSURANCE COMPANY, Ltd., announces that Mr. R. R. Mason, general manager, has been appointed a director. He will retire from the position of general manager on April 30, and will be succeeded by Mr. K. W. Bradshaw.

DR. C. A. HART has been appointed to succeed Mr. G. H. A. Hughes as director of the London Master Builders' Association. He will take up his duties as director designate at the beginning of April and assume full responsibility on September 1, when Mr. Hughes retires.

ENGLISH STEEL CORPORATION, Ltd., announces that Dr. H. H. Burton will retire from the board of directors on January 31, but will continue as research consultant to the Group until December 31, 1960. Mr. T. R. Middleton has been appointed a director, and director of research, with effect from February 1.

CENTRAL ELECTRICITY GENERATING BOARD states that Mr. Gordon Blain has been appointed fuel supplies officer to take charge of the fuel supplies branch of the operations department. He will be assisted by Mr. L. A. Didlick, who has been appointed fuel officer (supplies and technology) and by Mr. J. Laing, transport officer.

MR. C. H. SPENS, M.I.C.E., has been appointed chief engineer of the Ministry of Housing and Local Government, in succession to Sir George McNaughton, M.I.C.E., M.I.Mech.E., who is retiring on January 31. Mr. R. A. Elliott, A.M.I.C.E., a senior engineering inspector, succeeds Mr. Spens as a deputy chief engineer in the Ministry.

THE ELECTRICITY COUNCIL announces that Mr. F. L. Harris, M.I.E.E., regional safety officer for Yorkshire and the north-eastern region, has been transferred to the Midlands and East Midlands regions. Mr. E. K. Clarke, A.M.I.E.E., will be regional safety officer, Yorkshire and north-eastern region, in succession to Mr. F. L. Harris, with effect from February 15.

MOBIL OIL COMPANY, Ltd., states that Mr. B. R. Fraser has been appointed manager of a new manufacturing department at Caxton House, Tothill Street, London, S.W.1. He is responsible for co-ordinating the work of Coryton refinery, the blending works at Wandsworth and the blending works and grease plant at Birkenhead. Mr. J. W. Bartholomew has succeeded Mr. Fraser as manager of the refinery at Coryton, and Mr. C. E. Bean has been appointed assistant refinery manager.

JOSEPH SANKEY AND SONS, Ltd., announces that, following the resignation by Mr. K. S. Peacock from the position of chairman, Mr. H. F. Hodgson, managing director, has been appointed chairman and managing director. Mr. Peacock remains a director. Mr. G. B. Sankey, previously director and general manager of Hadley Castle Works, has relinquished that appointment on being appointed assistant managing director, but will retain special responsibilities for the operations of Hadley Castle Works. Mr. J. R. Martin, a director of the company, has been appointed general manager of Hadley Castle Works. Mr. R. P. Brookes, Mr. F. W. J. Hibbard and Mr. W. W. Watt have been appointed directors.

REYNOLDS T.I. ALUMINIUM, Ltd., and THE BRITISH ALUMINIUM COMPANY, Ltd., state that, as plans for the merging of their resources are now well advanced, the following changes of appointments are announced. The changes will take effect from February 1 and, pending completion of the plans, the new appointments will cover the operations of both companies. Mr. Gerald Lacey, commercial director, The British Aluminium Company, Ltd., to be executive director (forward planning). Mr. G. A. Anderson, director and general sales manager, The British Aluminium Company, Ltd., to be director of products and development. Mr. Basil James, chief executive (sales), Reynolds T.I. Aluminium, Ltd., to be director of sales. Mr. J. Salter, director and general production manager, The British Aluminium Company, Ltd., to be director of engineering. Mr. Paul R. McGehee, chief executive (production), Reynolds T.I. Aluminium, Ltd., to be director of production (manufactured products). Mr. W. B. C. Perrycoste, director and general production manager, The British Aluminium Company, Ltd., to be director of production (primary products).

## Business Announcements

THE LIGHTFOOT REFRIGERATION COMPANY, Ltd., has opened a new branch office at Canute Road, Southampton.

THE STAVELEY COAL AND IRON COMPANY, Ltd., has acquired the capital of Cyril Adams and Co., Ltd., New Barnet.

ISMAILIA VALVE COMPANY states that its temporary address is 21, Kensington Park Gardens, London, W.11 (telephone, Park 4920).

METALOCK (BRITAIN), Ltd., has opened an office at Windsor Chambers, Bearwood Road, Smethwick, Birmingham, 41 (telephone, Bearwood 2799).

BRITISH INSULATED CALLENDER'S CABLES, Ltd., states that the telephone number of its Erith Works, power cable division, has been changed from Erith 3030 to Erith 33030.

WEBLEY AND SCOTT, Ltd., announces that its address is now: offices, Park Lane, Handsworth, Birmingham, 21 (telephone, West Bromwich 2821); works, Birmingham Road, West Bromwich.

D. NAPIER AND SON, Ltd., has purchased a fleet of nine Convairliner 340 aircraft from United Air Lines, Inc., in order to establish a reserve of aircraft for immediate conversion to "Eland" engines and delivery.

G. AND J. WEIR, Ltd., states that the name of its service subsidiary in London and south-east England, W. R. Skinner, Ltd., has been changed to Weir, Drysdale Service (London), Ltd. The address at Caxton Street North, E.16, remains the same.

LEE GUINNESS, Ltd., has announced that its main sales engineering and contracts departments have been moved from the company's headquarters and factories in Northern Ireland to a newly-opened office at 25, Victoria Street, London, S.W.1 (telephone, Abbey 6762).

TURRET GRINDING WHEEL COMPANY, Ltd., Turret Works, Sunbury-on-Thames, announces that it has been appointed United Kingdom distributor for Diamond Boart blades for cutting germanium and silicon, manufactured by Diamond Tool Associates, Hawthorne, California, U.S.A.

SIMMONDS AEROCESSORIES, Ltd., Treforest, South Wales, has formed a company in Western Germany in association with Mecano-Bundy G.m.b.H., of Heidelberg, for the manufacture and sale of Spire Speednuts and other fastenings. The new company will be known as Mecano-Simmonds G.m.b.H.

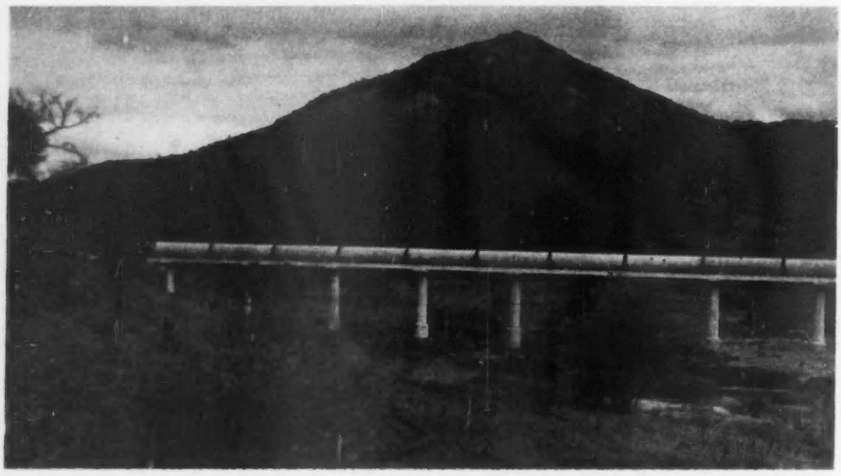
BRITISH OXYGEN GASES, Ltd., has undertaken development work in the United Kingdom in the tungsten arc cutting process, and is now marketing the equipment in arrangement with Union Carbide, Ltd. This process was originally developed by the Linde Company of the Union Carbide Corporation for form-cutting readily oxydised metals, such as aluminium, stainless steel, titanium and copper. The process depends upon a non-consumable electrode working in a gas stream and cuts these metals at a high rate.

DURAPIPE AND FITTINGS, Ltd., Durapipe Works, Winnock Road, West Drayton, Middlesex, states that a merger has been arranged with the plastic division of H. Incledon and Co., Ltd. Both companies are in the Incledon and Lamberts, Ltd., group, and the integration of their plastic activities has been arranged with the object of increasing efficiency and improving the service to their customers. The combined organisation, which will continue under the name Durapipe and Fittings, Ltd., will operate from Winnock Road. H. Incledon and Co., Ltd., will continue its other activities from its new and enlarged premises at Incledon House, 57, Sparkenhoe Street, Leicester.

STEEL AND CO., Ltd., has made an agreement with Unit Crane and Shovel Corporation of Milwaukee whereby the Corporation will manufacture Coles cranes in Milwaukee and will market these throughout U.S.A., Canada and Mexico under the name of "Unit-Coles," and R. H. Neal and Co., Ltd., will manufacture Unit cranes, excavators, draglines and backhoes in Grantham, and will market them throughout the world with the exception of U.S.A., Canada and Mexico under the name of "Neal-Unit," and subject to the existing Unit franchises in Australia, Union of South Africa, and the Benelux countries. A sales company has been registered, under the name International Crane and Excavator Corporation, with headquarters in New York for marketing Coles cranes and Unit cranes and excavators in the South and Central American Republics.

# Socoman Prestressed Pipeline in South Africa

BY OUR SOUTH AFRICAN CORRESPONDENT



THE laying of a Socoman-Freyssinet pipeline of prestressed concrete alongside a steel pipeline, both supplying water from the Umgeni Dam to Durban, should provide, in the years to come, some interesting data on the relative merits of these two installations. This pipeline, and also that from the Churchill Dam to Port Elizabeth, were constructed by the Socoman Company of South Africa, a subsidiary of the French organisation which created the Socoman pipe twenty years ago.

Socoman pipes have been constructed to meet pressures varying from 57 lb to 785 lb per square inch, and it has been reported that tests on a 63in penstock section in France passed the 950 lb per square inch mark. Many of these pipelines have been laid in North Africa where the constant growth of water requirements necessitates the development of water supplies to the cities and farms from storage points.

In concrete-lined steel pipes, the steel wall is stressed in tension and water-tightness diminishes as the elongation of the concrete increases. Seepage through to the steel, with consequent corrosion, is therefore always possible. Even if the concrete of such pipes is spirally reinforced, the chances of separation of the concrete from the steel cylinder remain.

The Socoman-Freyssinet pipe, which is designed to eliminate these shortcomings, is shown below. It is composed of a cylinder of centrifugally cast concrete *A*, compressed longitudinally by the hard steel wires *B* which are stressed between two cast iron end rings *C* which serve as joint rings. This core is wrapped circumferentially with a continuous helix of high elastic limit wire *D*, wound under tension. The exterior coating of concrete *E*, vibrated in place after the wrapping, ensures the protection of the wire.

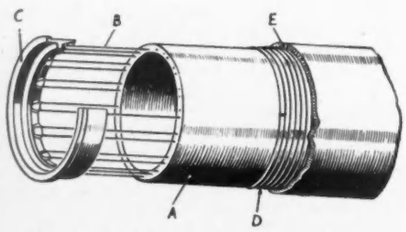



**Fig. 4—Details of Socoman prestressed pipe**

Fig. 1 shows the joining of two contiguous pipes. This is performed by wedging a rubber gasket between the two cast iron joint rings. These rings have been designed to provide a tight joint, regardless of the pressure, combined with sufficient flexibility for the pipe to adjust itself to the settlement of its bedding.

The prestresses are calculated so that in no case is the concrete stressed in tension while subjected to simultaneous internal pressure and external loads. It is claimed that should an

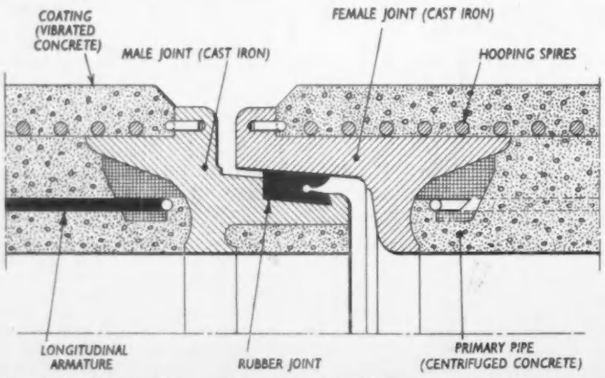



**Fig. 1—To form a joint a rubber gasket is wedged between jointing pieces at the ends of the pipe sections**

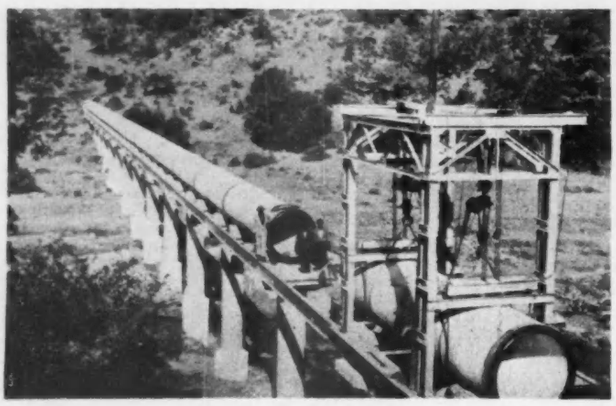


**Fig. 2—Apparatus for raising Socoman pipes to higher levels**

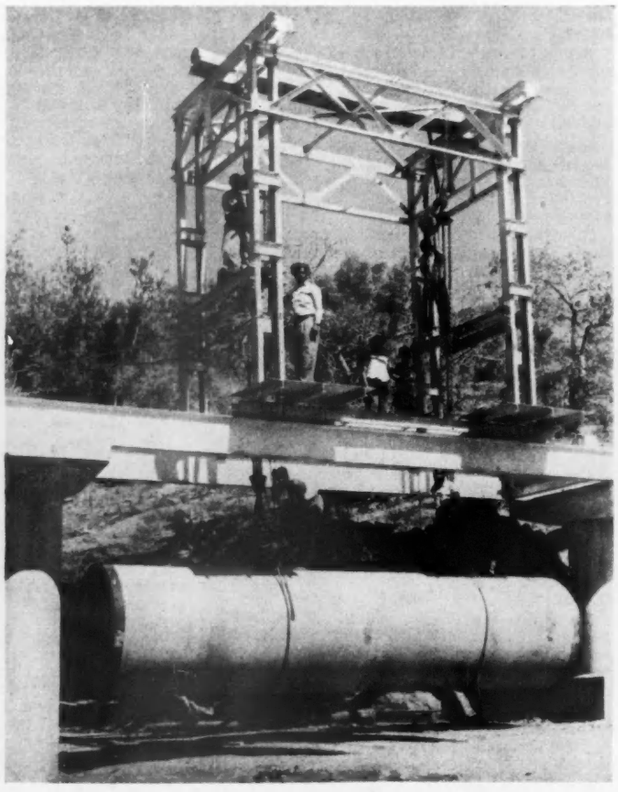


**Fig. 3—Raising pipes to viaduct level**

accidental pressure surge occur, the concrete will open up momentarily, permitting escape of the liquid, but, under the ensuing reduction in pressure, the concrete will close up due to the effect of the spiral reinforcement, and the pipe will regain its original compactness and water tightness.

The structural apparatus used for raising the sections of pipeline to higher levels is shown in Fig. 2, while Fig. 3 illustrates this in the process of raising a pipeline to the level of a river viaduct. The heading illustration shows such a viaduct in the completed state.

## New Railway Station at Cape Town

IT is now estimated that the new railway administrative offices at Cape Town will be completed by the end of 1960 and the railway station completed by about the middle of 1964. The total area covered will be in the region of 39 acres.

The new station is being built on the seaward side of the present station, the track between Cape Town and Woodstock being relaid and Woodstock station rebuilt. Fig. 1 shows the work in progress. The suburban platforms are in the centre of the picture and those for the main line trains are to the left. The area in the foreground will be the site of the concourse.

There will be twenty-four platforms of which five will be for main line trains, two for non-European trains and the remaining seventeen for the suburban trains serving Bellville, Cape Flats, and Simonstown lines. The main line platforms will be approximately 1500ft long and the suburban ones about 740ft. A concourse will run along the terminal end of all the platforms.

The main station building, fronting on Addersley Street and situated opposite the ends of the main line platforms, is to be a four-storey building. Main line platform 24 will be flanked on the seaward side by a parcels building 500ft long to handle all parcels and incoming baggage. There will be four dock platforms for the working of baggage and parcels traffic. The main concourse, running the full width of the twenty-four platforms on the Adderley Street side, will contain ticket offices and waiting rooms for European passengers. A pedestrian tunnel under the extended street will give access from the concourse to the parade. Non-European station facilities will be provided in two separate buildings straddling the tracks at the entrance to the station.

Facilities for handling postal matter are being installed and will consist of a chamber for sorting mails underneath the main line platforms and the distribution of these mails by conveyor systems through tunnels between the post office in Parliament Street and the mail chamber, and also for incoming mail between the Woodstock end of the station and the mail chamber. Incoming mail will be fed directly from each main line platform into chute-houses connected with the postal tunnels and conveyor systems.

Fig. 2 shows one of these tunnels under construction with the new platforms and shelters above and to the left. Work is at present confined to the construction of platform walls and roofing, postal tunnels and pedestrian subways. It is proposed to open the new station in stages as the work is completed.

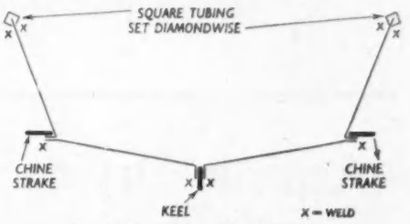
## Small Aluminium Alloy Craft in Durban Waters

ALUMINIUM alloys have now demonstrated that they are well suited for the building of small craft of many kinds. The ability of the metal to resist corrosion in fresh and salt water means long life with little or no maintenance.

Aluminium alloy boat

It is on record that some ships' lifeboats made of aluminium have been in service since 1935 and are still in excellent condition. An additional advantage is the fact that modern aluminium alloys combine great strength with light weight: and lightness are the main features of this virtually all-purpose runabout. It has a maximum beam of 5ft 8in, is 14ft long—plenty of room for fishing—and weighs only 260 lb, including the motor. Its general configuration is clear from the accompanying illustration.

The hull form enables it to plane easily




Method of construction

and, powered by an 18 h.p. outboard motor, its maximum speed is between 20 and 25 knots. Its draught, when carrying four adults, does not exceed 6in.

The hull is made of M57S half-hard 14 s.w.g. sheet, with a keel and two chine strakes of 50 s.w.g. extruded flat bar. The gunwale is made from extruded square aluminium alloy tubing split and set diamond-wise over the side plating on to which it is welded. The general method of construction is depicted above. The plating is bent out against the chine strakes and the formed keel plates come out from the keel—to which they are welded—to meet the side plates at a weld below the chine strakes. All welding was done using an argon tungsten welding set: ¼in M57S plate enables the stern to take the weight of the motor.

Four aluminium alloy flotation tanks are fitted to the boat, two as thwarts and two individual tanks each side at the stern. These tanks act as stiffeners for the transom and add considerably to the overall strength of the hull. Flooring is made from "Z" and "top hat" extruded aluminium alloy sections which are riveted into position. The aluminium and alloy sheet and extruded sections were supplied by the Aluminium Company of South Africa, Ltd.

an overall reduction in weight, draught and size of the power unit can, therefore, be achieved.

The boat illustrated in the accompanying photograph was built by A. J. Howes (Pty.), Ltd., of Durban, which has recently entered the boat-building industry. Designed primarily for fishing—and also for water-ski-ing—spaciousness

Fig. 1—Work in progress on the platforms

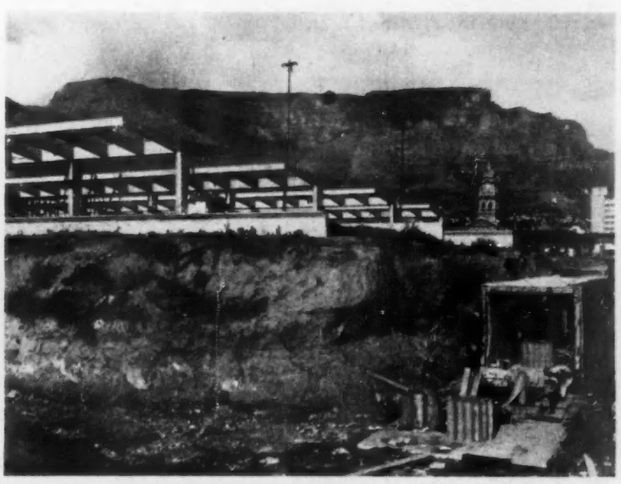


Fig. 2—One of the new tunnels under construction

# CONTINENTAL AFFAIRS

*by Our Continental Editor*

## Asphalt Drying and Mixing Plant

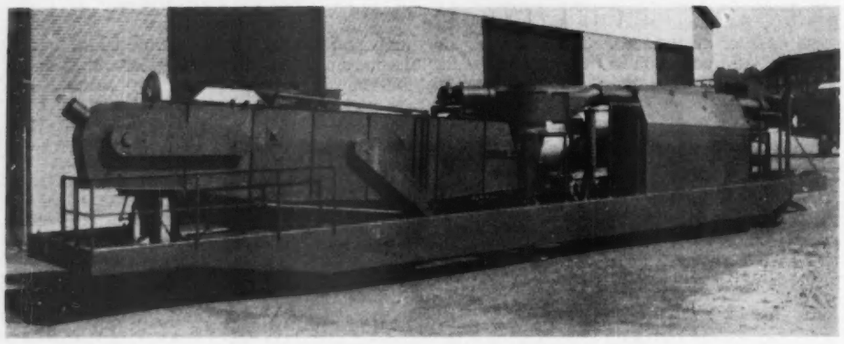


Fig. 1—Asphalt plant in transport position

THE range of asphalt plants made by H. Nielsen og Søn Maskinfabrik A/S, Copenhagen, has been extended by the self-contained, portable plant shown in the accompanying illustrations.

The "Via Nova" model "VN Combi" constitutes a compact machine with a capacity of 15 tons per hour at 7 per cent humidity, and 25 tons per hour at 2 per cent humidity. It has a two-compartment cold aggregate feeder with cold elevator, and a drying and mixing section comprising a drum dryer, drum feed belt, oil burner, combined high- and low-pressure pans, and an 80cm diameter cyclone precipitator with filter gate in the bottom outlet. In addition, the plant is equipped with two 6½ cwt oil tanks, closed hot elevator, hot storage bins, precision scales for stone materials and filler, and a twin-shaft mixer with abrasion-resistant wear plates.

The asphalt boiler is fitted with a kerosene burner and arranged to melt asphalt in barrels. It has a capacity of 5 tons, or 7 tons without the special means for barrel melting. A device equipped with circulating and charge pumps serves to measure accurately the quantity of asphalt.

The plant is powered by a six-cylinder, 75 h.p. diesel engine, and is mounted on rubber tyres. It can be erected in the course of a few hours or re-arranged into its transport position when it is suitable for road or rail transit.

In operation, the plant is run from a central position by means of five control levers which proportion the stone and filler, add the asphalt, and open or close the counterbalanced grate of the mixer.

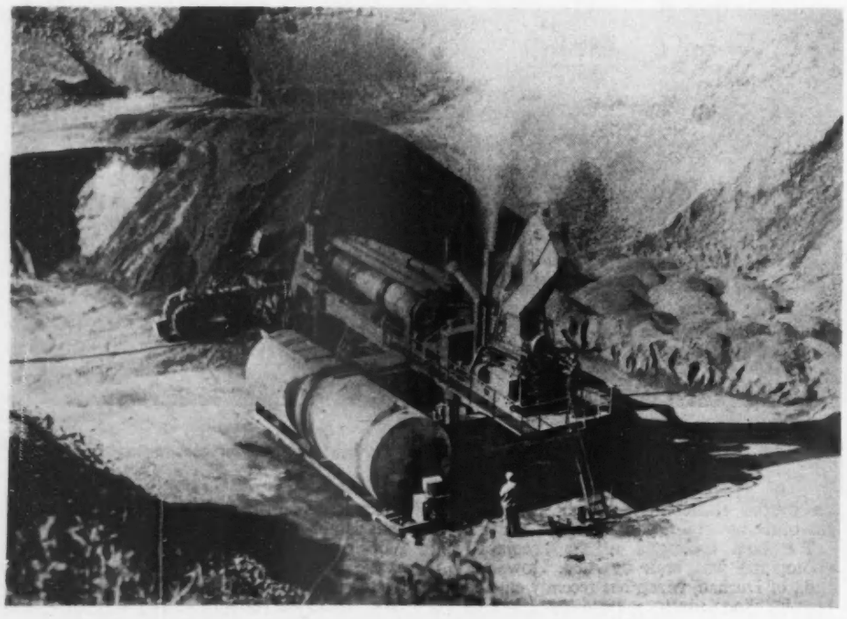


Fig. 2—Drying and mixing plant for asphalt in operation

## Seven-Mile Descent of Bathyscaphe

AT 2.10 a.m. on January 23, the bathyscaphe "Trieste" reached the bottom of the sea at 37,800ft in the Marianas trench, the deepest known point of the oceans. The descent began at 9.22 p.m. on the preceding night, and after staying at the bottom for thirty minutes, the craft ascended and broke surface at 5.57 a.m. The descent was made by Monsieur Jacques Piccard, the Swiss scientist, and Lieutenant Don Walsh, of the United States Navy. The two men survived their eight-and-a-half hours stay in the bathyscaphe's steel sphere without ill-effects, except that they appeared to be suffering from cold and dampness, the latter possibly due to condensation. Preliminary reports say that contact with the surface during the trip was maintained by sonar telephone down to a depth of 3000ft and then ceased. It is, of course, a well-known fact that while sound is readily transmitted by water, the propagation of sound waves is distorted by density gradients caused by differences in temperatures which give rise to refractions and internal reflections.

Another point of interest is the question of whether life exists at such great depths. Besides its great theoretical interest, the matter has some practical importance, for in the absence of living creatures it might be safe to use the deep oceans as dumping grounds for radioactive wastes. It appears, however, that living organisms were seen when the searchlights were turned on.

The descent was made during the night so as to afford the maximum amount of daylight for finding the surfaced bathyscaphe, which can be carried a long way from the surface craft.

The principle of the bathyscaphe was conceived by Auguste Piccard, father of Jacques Piccard and famous for his balloon ascent before the war. It is basically a submarine balloon, comprising a pressure-resisting steel gondola suspended from a float. The oblong 50ft hull, of approximately circular section with pointed ends, carries about 30,000 gallons of petrol in ten compartments. These compartments communicate with the sea outside, so that inside and outside pressures are equal.

The steel sphere, approximately 6ft 6in in diameter, is carried under the float. The thickness of the sphere is 3½in and it possesses two principal openings, one for the access hatch and the other, at the opposite end, for the observation window. The axis of the steel sphere slopes downwards so that the hatch is above the midplane, while the window is below it. Hatch and conning tower are connected by a ladder gangway passing through the float. The window takes the form of a cone of plastic material. This shape offers a large proportion of supported area and at the same time gives a large angle of view, while the plastic is free from the danger of suddenly forming cracks.

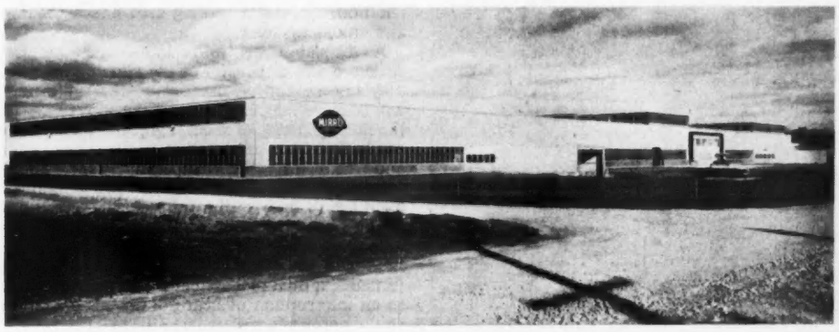
The main ballast is carried in the form of steel pellets, which are held in two containers fore and aft by keeping the exit passages sealed by magnetising the pellets. The arrangement "fails safe" for if the electrical current stops, the ballast is jettisoned and the bathyscaphe rises. For movement while submerged, two battery-driven propellers are provided, but the autonomy of the craft in this way is very limited owing to the small capacity of the batteries which can be carried. It is possible that the problem may be solved in a future design by installing a nuclear reactor.

The bathyscaphe "Trieste" was built in 1953 and so far has made over 100 descents, including a series of deep dives in the Tyrrhenian Sea off Naples in 1957.

# THE AMERICAN SCENE

*by Our American Editor*

## Aluminium Sheet Rolling Mill



*The Mirro Aluminum Company, of Manitowoc, Wisconsin, is about to put into production an aluminium rolling mill for flat products ranging from heavy-gauge sheet to "household" foil. The 240,000 square foot rolling mill building houses fully integrated plant with an initial capacity of 60,000,000 lb annually. All sheet and foil production of the mill will be used for the fabrication of the company's own products, which include cooking utensils, electric housewares, toys and giftware, aluminium boats and foil products.*

THE new sheet rolling mill of the Mirro Aluminum Company at Manitowoc, Wisconsin, is a good example of the current trend in the American metal fabricating industry toward integration. The firm is believed to be the largest manufacturer of aluminium cooking utensils in the world and recently has been diversifying its line of products to include toys, boats, foil items and builders' supplies. At a cost of about 12,000,000 dollars, the company has now built a modern integrated mill which will supply all of its aluminium flat product requirements once it reaches full production at an annual rate of 60,000,000 lb.

### Building Design

The main building measures 820ft by 250ft, and including the boiler room, pump room, loading docks and mill office, the total area is about 240,000 square feet of floor space. The lower part of the outside walls consists of 4ft high by 20ft long pre-cast concrete slabs, and above are 8ft high windows. The part of the wall above the windows is constructed of 19ft high sandwich panels consisting of an inner and outer face of aluminium sheet with 1½in of glass wool insulation in between. The windows on the east, south and west sides of the building are of blue glass to absorb the direct rays of the sun, yet admit sufficient light.

The floor of the mill is made chiefly of 8in thick slabs of concrete which have been surface-hardened and coated with a wax solution. However, the floor adjoining the melting furnaces consists of cast-iron plates pressed into concrete. The roof construction is of pre-cast concrete slabs placed on steel beams and then covered with felt and asphalt. Lighting varies from 20ft candles at the non-operating areas to 50ft candles in work areas where exceptional visibility is required. Heating and ventilating have been adjusted according to the requirements of the different areas so that the normal temperature will be 70 deg. Fah. throughout the mill. Because of the probability of higher working temperatures near the melting furnaces, the lunch room, foreman's office and quantometer room have been air conditioned.

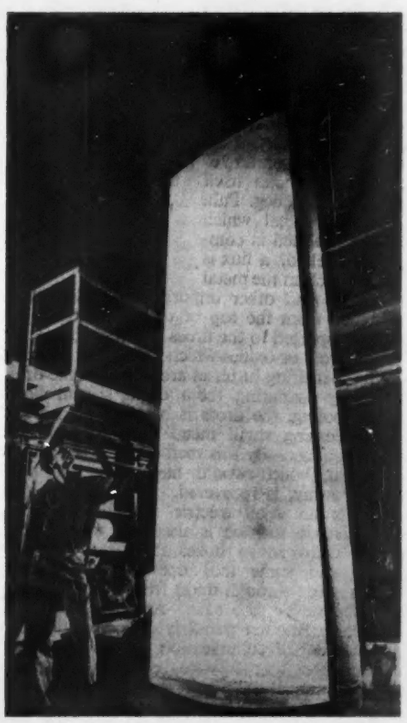


**Fig. 2—10in by 42in, 6000 lb rolling mill slab being removed from the pit of the Loma semi-continuous casting machine**

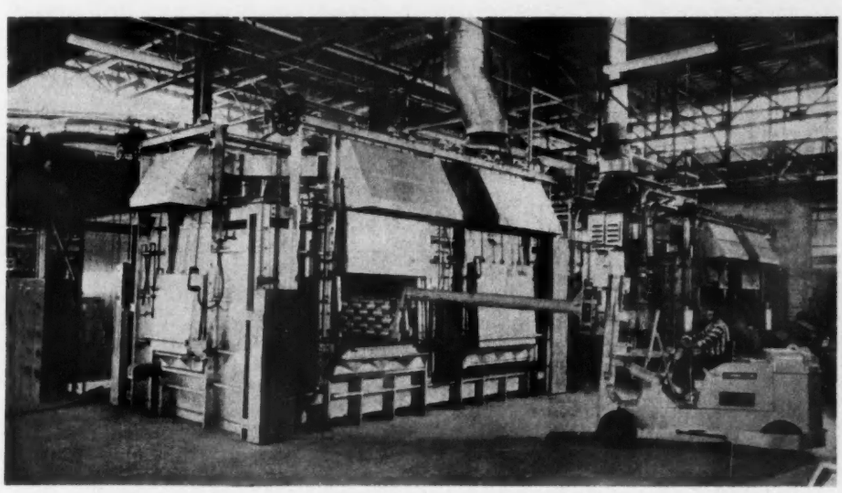


**Fig. 1—Charging of aluminium pigs by fork lift truck into one of the two 45,000 lb capacity Rockwell melting furnaces**

### Melting and Casting

Melting the aluminium in two large Rockwell melting furnaces is the first operation in the mill. Each furnace has a capacity of 45,000 lb. Pig and scrap are charged or placed into these furnaces by means of a lift truck, as shown in Fig. 1. The pig is picked up, run into the furnace, and lowered gently to the hearth of the furnace, after which the handling mechanism is withdrawn. Scrap loaded in boxes is run into the furnace in a similar fashion with the head of the mechanical handling device rotating to dump the scrap from the boxes into the melt. In this manner, the required amount of pig, scrap and

## THE AMERICAN SCENE *(Continued)*

alloy materials is charged into the furnace. Although the capacity of the furnace is 45,000 lb, only 20,000 lb to 24,000 lb of metal will be charged at any one time, the remainder of the 45,000 lb consisting of the molten heel from the previous melting down. This is a semi-continuous method of melting whereby there is always approximately one-half of a furnace load of molten metal available when the pig and scrap are added. The furnace is completely drained of the molten metal only at the end of the week or when the alloy is changed.

Since there is a risk of the metal "freezing up" in these furnaces in case of heat failure, the burners of the furnaces are designed to burn both gas and oil. Normally, the furnaces will be fired by gas; however, in case of gas interruption, fuel oil will be used as a standby. The atmosphere temperature within the furnace is about 1700 deg. Fah. while the temperature of the molten metal itself is about 1360 deg. Fah. When the metal which has been added is completely melted, a flux is added to clean the metal of oxides and other impurities. This dross is skimmed from the top of the melt into bogies and transported to the dross recovery room.

The dross or oxides which have been skimmed from the melting furnaces are cooled in the dross room by scattering them on a special floor. After cooling, the dross is broken up in a ball mill, releasing small metal particles from the waste product. By this method, a large amount of metal, which would have otherwise been thrown away, is recovered. Next to the dross room is an Ajax electric induction furnace. This electric furnace is used for melting fine scraps delivered in boxes from the stamping plants and some mill operations, or blown to this room through ducts from the foil slitter, slab scalper or slab saw. After melting these scraps, the molten metal is either poured into pig moulds for solidification and then charged into the melting furnace, or poured into a crucible and then transferred to the melting furnace.

Before the metal is transferred from the melting furnace to the Rockwell holding furnace, a round disc sample is taken to the quantometer room immediately north of the melting furnaces for analysis. One side of this disc is machined, and an electric arc is struck against the sample, the rays of light from this arc passing through various elements in the quantometer. The entire quantometer analysis, which takes approximately five to ten minutes, must be completed for each melt before it is approved and used. After the analysis is completed, the operator taps the metal from the melting furnace to the holding furnace. Here the metal is held at proper casting temperature and is thoroughly cleaned by a second fluxing process, similar to that in the melting furnaces. This furnace has a 30,000 lb capacity. Between 20,000 lb and 24,000 lb of metal are required for each actual cast of metal, leaving a reserve of between 6000 lb and 10,000 lb in the furnace at all times. The two holding furnaces also have a dual burner system for both gas and oil firing.

Situated between the two holding furnaces is a Loma semi-continuous casting machine employing the direct-chill process. On this unit, four slabs are cast simultaneously. Each slab is 12ft long, 10in thick and either 36in or 42in wide, as illustrated in Fig. 2. A 10in by 42in by 12ft long slab weighs 6000 lb ; thus 24,000 lb of slabs are produced per drop, about once per hour. The slabs are removed from the casting station by a large overhead crane. The casting station consists of the moulds, the large vertical hydraulic cylinder to support bottom stools for the slab moulds, a pouring trough and the controls for adjusting the flow of cooling water and the lowering speed of the hydraulic cylinder.

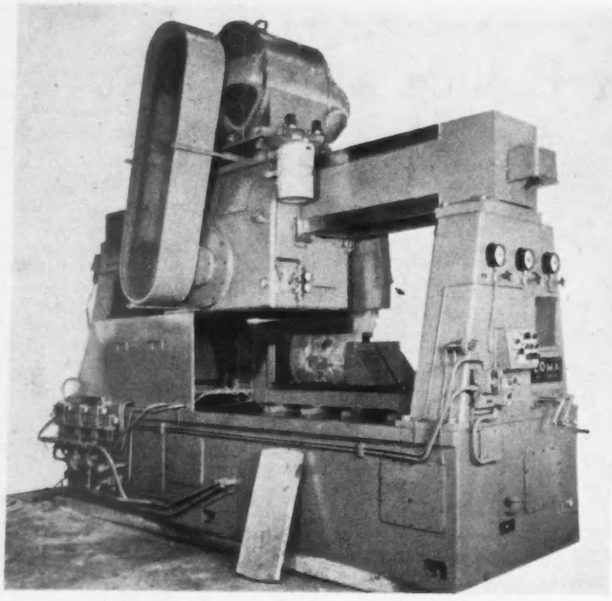


**Fig. 3—62in diameter Loma circular saw for sub-dividing up to 16in thick by 48in wide slabs at 6000ft per minute cutting speed**

As the drain plugs are pulled out of the holding furnace, the molten metal enters the moulds and the hydraulic cylinder is lowered. The molten metal is solidified against the mould walls and stools, and is lowered out of the bottom of the mould by movement of the hydraulic cylinder. To obtain the high quality slab required, a very delicate balance must be obtained between the hydraulic cylinder retraction rate, the flow rate and temperature of the cooling water, and the temperature of the molten metal.

From this point, the slabs are either stored at the south end of the building or loaded on to the homogenising furnace car to undergo a homogenising treatment. There are two Surface Combustion homogenising furnaces capable of holding 270,000 lb of slabs. In addition, there is a cooling area and a loading and unloading area.

As the slabs come from the casting station, the structure and dispersion of the alloying material may not be entirely uniform : the uniformity will be largely dependent upon the alloy cast. In the homogenising of sheet ingot, the metal slabs are heated to a temperature of 1050 deg. Fah. and held at this temperature for about forty-eight hours. Then the slabs are withdrawn from the furnace with a transfer car, put into a cooling area to cool and transferred to the unloading area. The homogenising furnaces are fired with gas. Unlike the melting and holding furnaces, a dual fuel system is not required here, as an interruption of heat during this operation would not result in damage to the metal.

The slabs in the as-cast or homogenised condition are then conveyed to a Loma high-speed slab saw which subdivides the 12ft long pieces into the shorter lengths required for hot rolling. Each slab, after being placed on the entry roller table by the conveyor, runs into the saw by means of motor-driven rollers. As shown in Fig. 3, the saw carriage with its 62in diameter blade is carried on a heavy cross-beam supported by sturdy uprights mounted on the welded body of the machine. The beam is fitted with fine-machined and hand-scraped surfaces matching with adjustable bronze shoes on the carriage. The saw carriage houses the saw arbor and intermediate gear shafts, which are all supported by adjustable Timken roller bearings. The gears are helical, precision cut and heat-treated before final machining. The main 100 h.p. motor is mounted on top of the carriage and connected to the gears by multiple "V"-belt drive. An oil-hydraulic pump unit, with motor, provides the energy both for the movement of the saw carriage and for the clamps to grip the stock during the sawing operation. Limit switches are provided to determine the desired

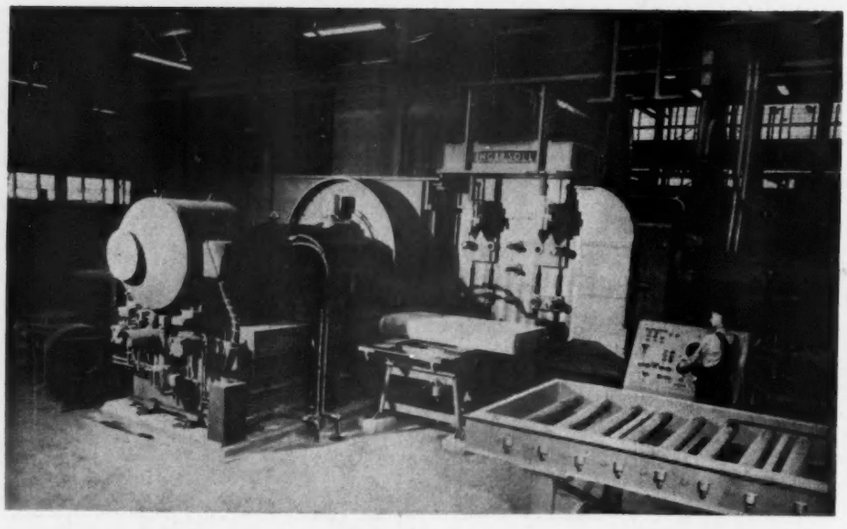
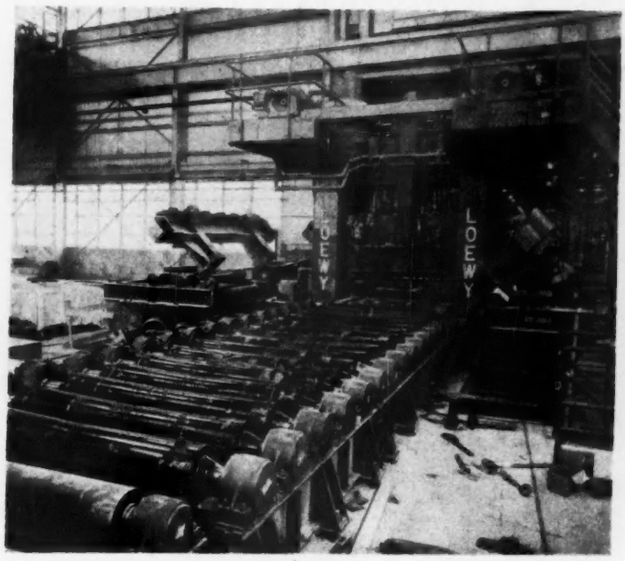
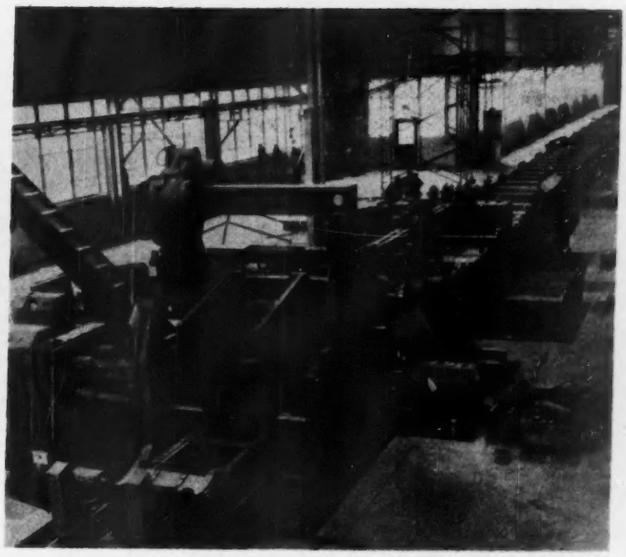


**Fig. 4—Ingersoll slab scalping machine capable of handling slabs up to 16in thick, 48in wide and 6ft long**



**Figs. 5 and 6—(Left) 32in diameter by 72in wide Loewy two-high reversing hot rolling mill for reducing 10in thick slabs down to $\frac{1}{16}$in gauge. (Right) Hot rolling mill run-out table with shearing, piling, edge trimming and upcoiling equipment**

stroke of the saw carriage to suit the various slab widths. The feed movement of the saw carriage cannot be started until the clamp has closed, and thereafter the clamp will not release the stock until the saw carriage has returned to the rest position, disengaging the saw blade from the stock. This automatic sequence safeguards the installation against any movement of the stock while the saw blade is in the cutting position, and prevents any risk of damage to the saw blade by neglect of the operator.

After leaving the slab saw, the slabs are rolled down the exit conveyor to the Ingersoll scalper, shown in Fig. 4. This machine is a milling machine which removes a cut of metal from the surface of the slab to provide a smooth surface for rolling. The scalper was designed to mill both sides of a slab at the rate of ten slabs per hour. The type of alloy cast will determine the extent of scalping required ; most of the hard alloys will require this operation. The scalper handles slabs up to 6ft in length, 8in to 16in thickness and in widths of 36in and 48in. This entire operation is done without lubrication, thus eliminating the necessity of cleaning prior to the reheating and hot rolling operations.

The next operation is to reheat the slabs to a temperature between 900 deg. and 925 deg. Fah. in one of the two Surface Combustion reheat furnaces. At the unloading end of the furnaces, the operator opposite the hot mill tables removes the slabs from the reheat furnaces and delivers them to the hot mill table from either furnace.

### Hot and Cold Rolling

The Loewy 32in by 72in two-high reversing hot rolling mill, illustrated in Fig. 5, reduces the slabs from the original 10in thickness to a final thickness of $\frac{1}{16}$in thick. The mill has a separating force capacity of 3,500,000 lb and employs two 50 h.p. screwdown motors, each having a range of 15in to 60in per minute. The table on the east side of the hot mill is about 250ft long, while the one on the west side is about 320ft long. At the end of the 320ft long table is the shearing, trimming and coiling equipment for putting the $\frac{1}{16}$in thick slabs into the form required by any particular order. A 2500 h.p. motor is used to drive the hot mill at speeds up to 500ft per minute. The hot mill requires four minutes to roll a slab from 10in to $\frac{1}{16}$in thickness.

Fig. 6 shows the west side run-out table, with shearing and piling equipment for flat sheets and plates and edge trimming and upcoiling equipment for coiled material.

The Loewy 15in and 42in by 60in four-high non-reversing cold rolling mill, together with its winder, is illustrated in Fig. 7. This mill is driven by a 1500 h.p. motor at speeds up to 1000ft per minute. The winding and unwinding reels of this mill are driven by 300 h.p. and 200 h.p. motors respectively. The coil size range of the reels is 20in i.d. by 44in o.d. The mill normally is fed with $\frac{1}{16}$in thick material which can be rolled down to a 0·012in minimum gauge. The screwdown system employs two 25 h.p. motors. Behind the mill, in a concrete block enclosed motor room, are all the controls, motor generator sets and electrical equipment required for the operation of the mill. In the basement below and around the mill foundation are the roll coolant and lubricating tanks and pumping equipment.

### Coil Slitting

After the metal is processed through the cold mill, it comes to the slitting area. One Stamco slitter, which is shown in Fig. 8, handles metal between 0·051in and $\frac{1}{8}$in thick ; the other one slits metal from 0·010in to 0·051in thickness. Coils from the storage area are placed on the walking beam conveyors. When the operator is ready to load the unwind mandrel of the slitters, the walking beam conveyor is operated to place one coil on the coil car in front of the walking beam conveyor. The walking beam conveyor rises and moves forward until the first coil is above the car. At this point the conveyor lowers, leaving the first coil on the coil car. The car transfers the coil on to the unwinder expanding drum. The sheet is then threaded through the slitting head and the individual slit strands are fastened to the rewinder collapsible drum. The entire line is then started and the metal is slit at an operating speed of 500ft per minute. The finished coils are pushed off the rewinder on to a turnstile arm and removed from the turnstile by means of fork-lift trucks. An adjacent enclosed area is the metal wash room where the coils of aluminium are thoroughly washed before going into the annealing furnaces.

### Foil Rolling

Because of the necessity of keeping the foil mill equipment clean and free of dust, which would contaminate the metal and cause pinholes to show up in the product, the foil mill is enclosed in a foil mill room which is pressurised by a blower system, admitting only filtered air. Although there is only one foil mill at the present time, the room is laid out for the possibility of adding two more foil mills. In addition to this, the next bay to the south provides space for three additional foil mills. Below the foil mill room is the oil basement containing the storage tanks for the roll coolant and lubricating oils.

The foil mill is illustrated in Fig. 10 and operates

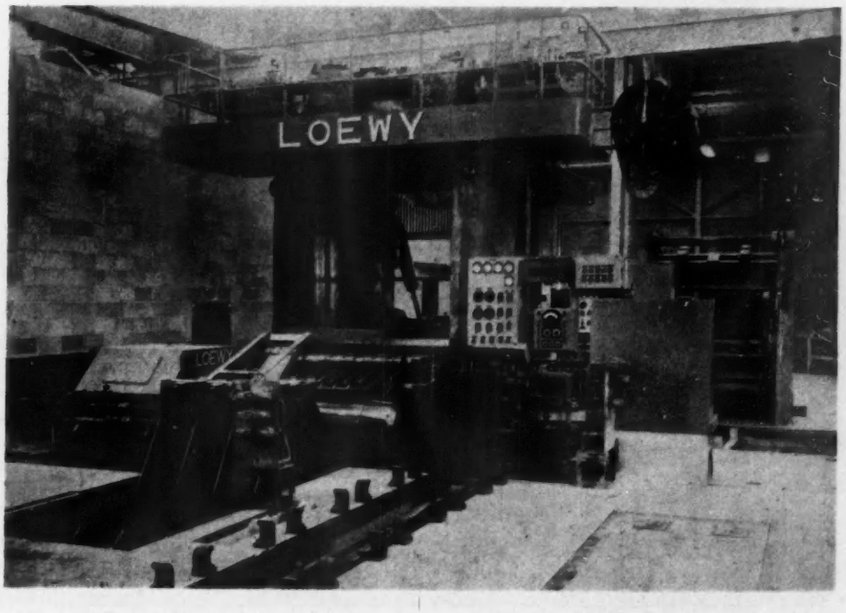
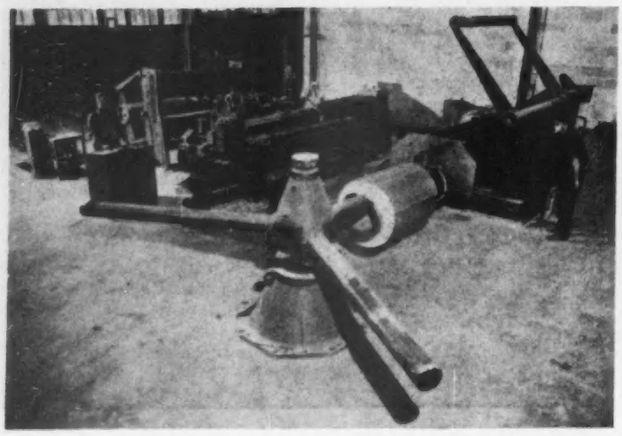
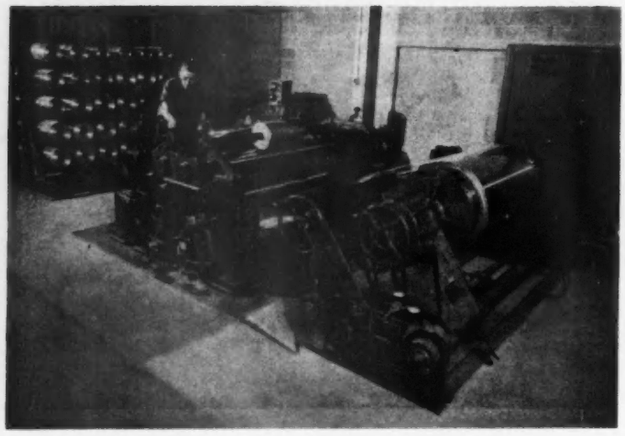



**Fig. 7—15in and 42in by 60in Loewy four-high non-reversing cold rolling mill with winding reel**

## THE AMERICAN SCENE *(Continued)*





**Figs. 8 and 9—(Left) Stamco No. 6½, 60in wide rotary gang slitting line with 100 h.p., 500ft per minute driver. (Right) Stamco foil slitting and separating machine with 0·006in to 0·00025in thickness range and maximum speed of 2000ft per minute**

up to a speed of 2200ft per minute. This speed is attainable only on the last pass in rolling the foil down to the "household" foil thickness of 0·0007in. The firm has been rolling on the first passes at speeds up to 800ft per minute and on the intermediate passes up to 1500ft per minute. The foil mill is a Loewy 9½in and 22in by 48in four-high non-reversing mill, equipped with a 1500 lb per square inch hydraulic screwdown system. The mill can roll foil from a 0·025in maximum starting material to a 0·00025in minimum finishing gauge. The main mill drive is a 600 h.p. d.c. motor, and the unwind reels and rewind reels have drives and drag generators of 125 h.p. and 25 h.p. capacity each, and can handle 20in i.d. by 44in o.d. coils.

On this mill there is an X-ray gauge for the control of metal thickness. The X-ray gauge is set for the desired thickness and, as the metal thickness varies from this preset thickness the gauge automatically compensates by speeding up or slowing down the mill, thereby increasing or decreasing the tension on the reels to correct the error. During the rolling operation, coolant oil is continually flooded over the rolls to remove the heat which is generated. On heavy reductions coolant oil flows at the rate of 500 gallons per minute, while on the lighter reductions the flow is cut down in relation to the amount of heat generated in the operation. When rolling the last pass of "household" foil, the desirable coolant flow is about 125 gallons per minute.

After rolling it is necessary to trim and slit the foil to the widths required. This is done on a Stamco foil slitter-separator unit shown in Fig. 9. The metal is unwound from the large spools and threaded through the slitting unit, where it is slit to the required widths and recoiled on smaller spools. The foil slitter makes use of razor blades or spring-loaded cup knives, depending on the thickness of foil being processed. For "household" foil, razor blades are used, the materials being cut to three 12in width coils from a 36in wide coil, at a maximum speed of 2000ft per minute. In addition to the "household" foil, the equipment will handle to 0·006in maximum thickness and a minimum of 0·00025in doubled foil.

The new mill was planned and designed by the firm's rolling mill committee, under the chairmanship of Mr. A. L. Vits, and the Klug and Smith Company, of Milwaukee, Wisconsin, was the building and plant installation contractor.

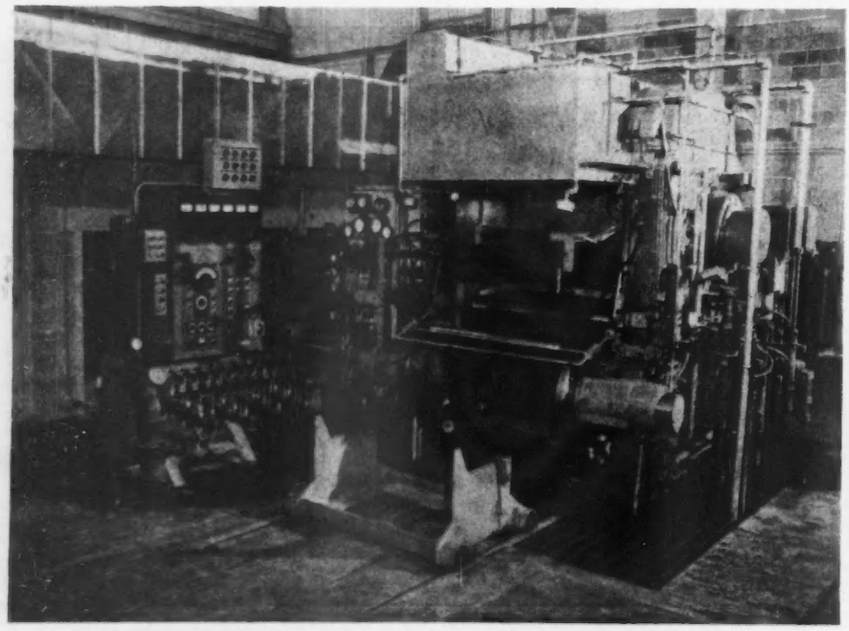


**Fig. 10—9½in and 22in by 48in Loewy four-high non-reversing foil rolling mill**

### Dr. Glenn T. Seaborg Receives Enrico Fermi Award

DR. GLENN T. SEABORG, the eminent nuclear scientist and Chancellor of the University of California, has received the Atomic Energy Commission's Enrico Fermi Award for 1959. The award, consisting of a medal, a citation and 50,000 dollars, was presented to Dr. Seaborg for his outstanding work in the field of nuclear chemistry, including the discovery of plutonium and other trans-plutonium elements, and for his leadership in scientific and educational affairs. The award was recommended by the General Advisory Committee of the Commission and was approved by President Eisenhower. Dr. Seaborg was presented with the award at a ceremony in the auditorium at the Commission's headquarters in Germantown, Maryland, on December 2, 1959, the seventeenth anniversary of the day the late Enrico Fermi and his team of nuclear scientists proved that nuclear fission could be self-sustained and controlled when they operated the world's first reactor in a squash court under the stadium at Stagg Field at the University of Chicago.

The documentation in support of the Committee's recommendation, reads: "Dr. Seaborg is a pioneer in the field of nuclear chemistry, and he has attained international renown as a great leader in that field. His discovery, with Kennedy and Wahl, of the element plutonium, together with his elucidation of its chemistry by experiments when only the most minute amount of that element was available, constitute a major scientific achievement. This work made possible the plutonium reactor cycle. Dr. Seaborg's latest work in the discovery of the now lengthy series of elements heavier than plutonium and the investigation of their properties has contributed in a major way to our understanding of nuclear structure and the chemistry of the heavy elements. Dr. Seaborg is also an outstanding leader in scientific and educational affairs. He has served on several of the most important Government committees and is now Chancellor of the University of California at Berkeley. Many students have received their training in nuclear chemistry as well as inspiration and enthusiasm for a scientific career from Dr. Seaborg. He was also one of the first to appreciate the opportunity offered by television to communicate knowledge and understanding of science to a broader audience. American science is stronger in many respects because of the outstanding contributions of Dr. Seaborg."

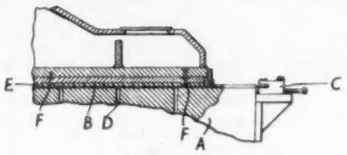
# BRITISH PATENT SPECIFICATIONS

*The dates printed are those of application and publication on completion. Copies of specifications may be obtained at the Patent Office Sales Branch, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each.*

## MACHINE TOOLS

**824,576.** July 3, 1957.—SLIDE AND WAY STRUCTURE FOR A MACHINE TOOL, Kearney and Trecker Corporation, 6784 West National, City of Milwaukee, State of Wisconsin, United States of America.

The principal object of this invention is to provide a way surface for a machine tool which presents a continuous unbroken surface and has a smooth rolled surface devoid of sharp peaks and valleys. The drawing shows an enlarged view, taken longi-

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tudinally through one of the gantry shoes and its associated way support of a gantry type milling machine. The bed ways *A* of the machine are constructed to predetermined dimensions which are maintained during the life of the machine tool as they are not subjected to direct wear. On the top supporting surface of the way, there is a continuous ribbon way strip *B* of cold rolled stainless steel that presents a smooth unbroken bearing surface characterised by a rolled surface as compared to the finished surface of sharp peaks and valleys produced by machining or grinding. At the ends of the bed tensioning blocks *C* securely hold the ends of the ribbon way strip. To prevent cutting fluids and lubricants from accumulating between the strip and the top of the way, the longitudinal edges of the strip are sealed by a "Neoprene" strip. Any fluid accumulating under the way strips is exhausted through the passages *D* thereby preventing a building up of hydrostatic pressure. To minimise the effect of friction between the gantry shoes and the ribbon way strips, the shoes are provided with a non-metallic bearing plate *E* of a plastic material. Lubricant is supplied to the area of the ribbon way strip that is in immediate contact with the surface of the bearing plate through grooves *F* longitudinally spaced over the length of the plate. The termination of these grooves short of the sides of the bearing plate minimises the amount of lubricant that will seep out and tend to be drawn by capillary action under the ribbon way strip.—*December* 2, 1959.

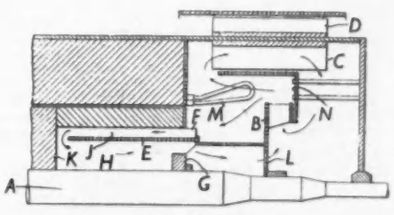
**826,462.** February 21, 1956.—TIE-RODS FOR POWER PRESSES AND OTHER MACHINE TOOLS, Hordern, Mason and Edwards, Ltd., Woodlands Farm Road, Tyburn, Birmingham. (*Inventors: Ronald Frederick Deykin and Thomas Howard Burton.*)

The invention relates to power presses and machine tools in which the frame or body of the machine is provided with one or more tie-rods prestressed in tension. During the assembly of the machine the tie-rods are generally heated before the nuts at their ends are tightened. The tie-rods then on cooling contract and produce the requisite tensile pre-loading in each rod. The necessity for loosening the nuts of tie-rods sometimes arises in power presses when the ram becomes jammed at the lower end of its stroke due to some defect or maladjustment in the tools or the workpiece, and under these conditions it is necessary to heat the rods. To facilitate this heating the tie-rods described are provided with an internal electric heating element extending for a substantial distance into the rod so that when energised the element effects the required longitudinal thermal expansion to enable the nuts to be loosened,—*January* 6, 1960.

## ELECTRIC TRACTION

**826,497.** October 11, 1956.—ELECTRIC CURRENT RECTIFYING ARRANGEMENTS, The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2. (*Inventors: John Burnett Borthwick and James Durno Mitchell.*)

This invention relates to a method of regulating a rectified voltage by connecting several rectifiers to different tappings on a transformer and causing selected rectifiers to conduct according to the voltage required. One such arrangement, as it might be applied to a locomotive operating on high-voltage a.c. at 50 c/s, is shown in the diagram. The transformer has a centre-tapped secondary winding *A* which is provided with a number of tappings symmetrically arranged about the centre tapping and providing various voltages with respect to the centre tapping. A number of similar mercury arc rectifiers *B* are arranged to be supplied from the transformer, the anode of each rectifier being connected to a different tapping on the secondary winding and the cathodes being connected together to form the positive terminal of a direct current supply to a direct current traction motor *C*. Each mercury arc rectifier has an exciting electrode near the cathode which is maintained at a positive potential with respect to the cathode. Each exciting electrode is connected via a switch *D* and a smoothing inductance to the positive terminal of a direct current supply *E*. An electromagnetic ignition device (not shown) is associated with each rectifier and is arranged to be operated automatically in dependence upon the voltage between the cathode and the exciting electrode. This voltage will be too small to operate the device when the rectifier is conducting but, providing a switch *D* is closed, will rise to the necessary value

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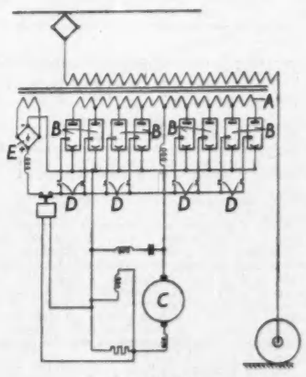
if the rectifier is not conducting. In operation only two of the rectifiers will be conducting normally, these being connected to a pair of corresponding transformer tappings on either side of the centre tapping. The switches *D* in the exciting circuits of these two rectifiers are closed while the switches in the exciting circuits of the remaining rectifiers are open. In order to change from one pair of tappings to another pair, the excitation circuits of the pair of rectifiers connected to the required transformer tappings are completed, these rectifiers then being ignited automatically, and the switches in the excitation circuits of the other two conducting rectifiers are opened, whereupon they cease to conduct.—*January* 6, 1960.

## ELECTRICAL ENGINEERING

**826,423.** January 28, 1957.—COOLING OF FLAME-PROOF MOTORS, Metropolitan-Vickers Electrical Company, Ltd., St. Paul's Corner, 1–3, St. Paul's Churchyard, London, E.C.4. (*Inventors: John Kenneth Vose and George Willoner.*)

The object of this invention is to cool the rotors of flame-proof machines without introducing con-

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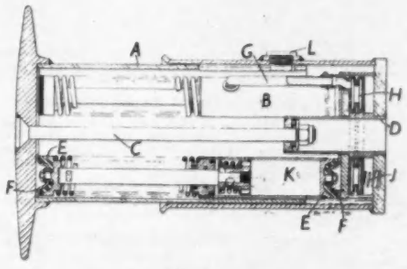
ditions which will cause easy ignition of combustible gases which exist in the motor. It utilises cooling ducts in the rotor, but since these ducts have entry and exit apertures at the same end of the rotor, there is no narrow neck connecting the two ends of the rotor, thereby allowing the passage of a pressure wave and a flame from one end of the motor to the other. The cooling system according to the invention is therefore suitable for use where gases of Group III as defined in B.S. 229 (that is ethylene and the like) may be present in the coolant fluid. Referring to the drawing, which shows a portion of the rotor of a flame-proof machine, the shaft *A* of the rotor has a fan *B* mounted on it; *C* and *D* are the fins of a heat exchanger attached to the circumference of the frame, extending radially inwards and outwards. The flat bars *E* are welded between successive arms *F*, welded to ring *G* attached to the shaft, and form ducts *H* and *J* which extend axially as far as the laminations *K*. The operation of the cooling system is as follows. The fan *B* causes circulation of cooling fluid along paths as indicated by the arrows. Two alternative paths are shown, the first through each of the cooling ducts *H* and *J* in the rotor and out through the holes *L* and back to the blades of the fan, and the second over the stator end windings *M* along the fins *C* of the heat exchanger, where heat is given up to the fins and deflected by the baffle *N* back to the blades of the fan. The cooling fluid absorbs heat from the rotor in the ducts and from the stator end windings and gives it up to the heat exchanger by passing along fins *C*. The second cooling fluid on passing between stator *P* and the outer fins *D*, removes heat from the latter. The figure shows only one end of the rotor and it is assumed that the other end of the rotor is cooled by a similar method.—*January* 6, 1960.

## RAILWAY VEHICLES

**826,170.** April 9, 1958.—BUFFING GEAR FOR RAILWAY AND LIKE VEHICLES, Moulton Developments, Ltd., The Hall, Bradford-on-Avon, Wiltshire. (*Inventor: Alexander Eric Moulton.*)

This buffing gear is described with reference to the accompanying drawings. A cylindrical buffer

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case for mounting on the vehicle headstock has tubular buffing plunger *A* carrying at its outer end a buffer head and enclosing a number of telescopic hydraulic units *B* between the head and the flange plate. The buffer head encircles a central stem or rebound rod *C* having at its inner end a nut and rubber cushion, which limits the outward movement of the buffer. The flange plate carries a tubular spigot *D* with an abutment for the rebound rod. The hydraulic units *B* are assembled into a stack by bolting each of their extremities *E* to endplates *F* resiliently mounted with an intervening rubber cushion. From each cylinder of the hydraulic units a conduit *G* leads to a common reservoir *H* adjacent to the flange plate. The reservoir comprises a flexible diaphragm pressurised by helical springs *J* seated in the flange plate. Surrounding the telescoping stem of each hydraulic unit is a helical steel recoil spring for returning the buffer head to its outermost position. On inward movement of the buffer head during the buffing operation, hydraulic fluid contained within the space *K* is forced through channels in the piston and a spring loaded valve to the opposite side of the piston. During the rebound stroke, when the helical coil springs return the buffer head to its outer position, the fluid in each unit is passed through the conduits *G* into the reservoir. The fluid is returned to the units by the pressurising effect of the springs *J* on the reservoir. A screw *L* in the buffer case rides in a groove in the buffing plunger and limits the stroke.—*December* 31, 1959.

## Launches and Trial Trips

BRITISH GANNET, oil tanker ; built by the Blythswood Shipbuilding Company, Ltd., for B.P. Tanker Company, Ltd.; length between perpendiculars 495ft, breadth 69ft, depth 37ft, deadweight 15,262 tons on 29ft 4½in draught ; twenty-seven cargo oil tanks, two cargo pump rooms, one 75kW steam-driven and two 250kW diesel-driven generators ; Kincaid-Harland and Wolff diesel engine, six cylinders 750mm diameter by 2000mm combined stroke, 8600 b.h.p., loaded trial speed 16 knots. Trial, November 5.

## Forthcoming Engagements

*Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the* TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

### ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

*To-day, Jan.* 29.—COVENTRY AND DISTRICT BRANCH : E.M.E.B. Sports and Social Club, Merrick Lodge, Sandy Lane, Coventry, Visit by C. G. F. Aldridge (National Chairman), and E. A. Bromfield (General Secretary), 7.45 p.m.

*Mon., Feb.* 1.—BOLTON BRANCH : Railway Hotel, Trinity Street, Bolton, "The I.E.E. Regulations," H. F. Smith, 7.45 p.m. ★ ESSEX BRANCH : Angel Hotel, Ilford, Essex, Film Show 8 p.m. ★ LEEDS BRANCH : Great Northern Hotel Leeds, "The Application of Temperature Control," A. P. Bellis 7.30 p.m. ★ SHEFFIELD BRANCH : Royal Victoria Hotel Sheffield, "Development of M.I.C.C. Cables and their Applications," R. J. Cotton, 7.30 p.m.

*Tues., Feb.* 2.—ALDERSHOT AND DISTRICTS BRANCH : Station Hotel, Basingstoke, Hants, "P.V.C. Mains Cables," R. H. Bunch and S. G. Crooks, 7.30 p.m. ★ NOTTINGHAM BRANCH : LEICESTER AREA : Westcotes Constitutional Club, off Narborough Road, Leicester, "Recent Developments in Winding Wires," A. J. Taylor, 7.30 p.m. ★ READING AND DISTRICTS BRANCH : "Marquis of Lorne," Friar Street, Reading, "Crime and the Public," Chief Inspector Dolby, 7.30 p.m. ★ WEST LONDON BRANCH : Windsor Castle Hotel, 134, King Street, Hammersmith, London, W.6, "Protective Equipment for Industrial Plant," W. L. Stern, 7.30 p.m.

*Wed., Feb.* 3.—HALIFAX BRANCH : Crown Hotel, Horton Street, Halifax, "Transistors," 7.45 p.m. ★ MANCHESTER BRANCH : Engineers' Club, Albert Square, Manchester, 2, "Himalayan Journey," E. Courtney, 7.15 p.m. ★ NORTH LONDON BRANCH : Wood Green Civic Centre, Town Hall, Wood Green, London, N.22, "Electrical Accidents in the Home," S. J. Emerson, 8 p.m.

*Fri., Feb.* 5.—LIVERPOOL AND DISTRICT BRANCH : Industrial Development Centre, M.A.N.W.E.B., Paradise Street, Liverpool, 1, "Branch Lecturettes," J. L. Blakemore and E. J. Mulholland, 7.30 p.m. ★ STOKE AND CREWE BRANCH : Grand Hotel, Hanley, "Refrigeration," T. Pearce, 7.30 p.m.

### BRITISH COMPUTER SOCIETY

*Mon., Feb.* 1.—GLASGOW BRANCH : Royal College of Science and Technology, Glasgow, "Problems Involved in Applying a Computer to Commercial Work," H. W. Gearing, 6.45 p.m.

*Tues., Feb.* 2.—MIDDLESBROUGH BRANCH : Constantine Technical College, Borough Road, Middlesbrough, "Computer Techniques for the Recording of, and Reference to, Data," A. S. Douglas, 7.30 p.m. ★ NEWCASTLE BRANCH : University Computing Laboratory, 1, Kensington Terrace, Newcastle, "Data Transmission in Relation to Computers and Data Processing Systems," W. S. Ryan, 7 p.m.

### BRITISH INSTITUTION OF RADIO ENGINEERS

*Tues., Feb.* 2.—MERSEYSIDE SECTION : University Club, Liverpool, "Distribution of Sound and Television by Wire," A. W. Mews, 7 p.m. ★ SOUTH MIDLANDS SECTION : Winter Gardens, Malvern, "Electronics in Medical and Biological Research," W. J. Perkins, 7 p.m.

*Thurs., Feb.* 4.—NORTH WESTERN SECTION : Reynolds Hall, College of Technology, Sackville Street, Manchester, "Acoustics in Modern Buildings," E. S. Benson, 6.30 p.m.

### BRITISH INTERPLANETARY SOCIETY

*Tues., Feb.* 2.—Lancaster Room, Caxton Hall, London, S.W.1, "The Use of Reinforced Plastics in Rockets," A. Wilson, 7 p.m.

### ILLUMINATING ENGINEERING SOCIETY

*Wed., Feb.* 3.—EDINBURGH CENTRE : Concert Hall, Y.M.C.A., Edinburgh, "Lighting and Safety in Building Operations and Works of Engineering Construction," J. Gordon Scott, 7.30 p.m. ★ NEWCASTLE UPON TYNE CENTRE : Room B7, Percy Buildings, King's College, Queen Victoria Road, Newcastle upon Tyne, 1, "An Outline of Television Studio Lighting Problems," R. Koplick, 6.15 p.m.

*Thurs., Feb.* 4.—NOTTINGHAM CENTRE : Electricity Centre, Carrington Street, Nottingham, "Subjective Responses in Lighting Design," A. M. Marsden, 6 p.m.

### INSTITUTE OF FUEL

*Tues., Feb.* 2.—NORTH-EASTERN SECTION : Chemistry Lecture Theatre, No. 3, King's College, Newcastle upon Tyne, "Developments in Atomic Energy," H. M. Finniston, 5.30 p.m.

*Thurs., Feb.* 4.—MERSEYSIDE SUB-SECTION : Liverpool Engineering Soc ety's Rooms, 9, The Temple, Dale Street, Liverpool, "Water Treatment," C. J. Carter, 7 p.m. ★ MIDLAND SECTION : Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, 2, "Symposium on Torquay Conference," H. E. Crossley, 6.30 p.m.

*Fri., Feb.* 5.—SOUTH WALES SECTION : South Wales Institute of Engineers; Park Place, Cardiff, "British and Continental Practice in the Fuel Industry," W. Idris Jones, 6 p.m.

### INSTITUTE OF MARINE ENGINEERS

*Mon., Feb.* 1.—STUDENT LECTURE : Memorial Building, 76, Mark Lane, London, E.C.3, "The Instrumentation of Marine Machinery," F. P. Rout, 6.30 p.m. ★ SOUTH WALES SECTION : Welsh College of Advanced Technology, Cathays Park, Cardiff, "Safety at Sea," S. Hogg, 6.45 p.m. ★ MERSEYSIDE AND NORTH WESTERN SECTION : Liverpool Engineering Society, The Temple, Dale Street, Liverpool, Annual General Meeting, "Centrifugal Purification of Oils for Marine Service," M. E. O'Keeffe Trowbridge, 6 p.m.

### INSTITUTE OF PETROLEUM

*Wed., Feb.* 3.—61, New Cavendish Street, London, W.1, "Regional Trends in Crude Oil Gravities in the Middle East," Y. P. Wilson, 5.30 p.m.

### INSTITUTE OF REFRIGERATION

*Thurs., Feb.* 4.—Institute of Marine Engineers, Memorial Building, 76, Mark Lane, London, E.C.3, "Polyurethane Foams : Their Contribution to Heat Insulation," J. M. Buist and R. Hurd, 5.30 p.m.

### INSTITUTE OF SHEET METAL ENGINEERING

*Wed., Feb.* 3.—NORTH-WEST BRANCH : Engineers' Club, 17, Albert Square, Manchester, "Uses of Plastic Coated Sheet Steel," R. G. Timms, 7 p.m.

### INSTITUTION OF AGRICULTURAL ENGINEERS

*Mon., Feb.* 1.—WEST MIDLANDS CENTRE : Lecture Hall G.11, Gosta Green Technical College, Birmingham, Forum, "Standardisation of Farm Machinery," R. Berry, J. M. Chambers, C. Culpin and R. W. Ward, 7.30 p.m.

### INSTITUTION OF CHEMICAL ENGINEERS

*To-day, Jan.* 29.—NORTH WESTERN BRANCH : Midland Hotel, Manchester, Annual General Meeting, 3.30 p.m.

*Wed., Feb.* 3.—MIDLANDS BRANCH : Midland Hotel, Birmingham, "The Exchange of Deuterium between Hydrogen and Liquid Ammonia," P. J. Bourke and J. C. Lee, 6.30 p.m.

### INSTITUTION OF ELECTRICAL ENGINEERS

*To-day, Jan.* 29.—ELECTRONICS AND COMMUNICATIONS SECTION : Savoy Place, London, W.C.2, "Beam-Type Parametric Amplifiers : Some Aspects of Design and Use," R. B. Dyott and C. R. Russell, 5.30 p.m.

*Mon., Feb.* 1.—LONDON GRADUATE AND STUDENT SECTION : R.A.F. Technical College, Henlow, Beds, "Inertial Navigation Systems," E. W. Anderson, 7.45 p.m. ★ MERSEY AND NORTH WALES CENTRE : Donnan Laboratories, Vine Street, Liverpool, "Frequency Variations of Quartz Oscillators and the Earth's Rotation in Terms of the N.P.L. Caesium Standard," L. Essen, J. U. L. Parry and J. McA. Steele, 6.30 p.m. ★ NORTH-EASTERN MEASUREMENT AND ELECTRONICS GROUP : Rutherford College of Technology, Newcastle upon Tyne, "The Oral Presentation of Scientific Material," A. Clow, 6.15 p.m. ★ SOUTH MIDLAND CENTRE : James Watt Memorial Institute, Birmingham, "The 'Deltic' Locomotive," C. M. Cock, 6.30 p.m. ★ SOUTH MIDLAND CENTRE : Winter Gardens, Malvern, "Electronic Aids to Banking and Commerce," R. Feinberg, 7.30 p.m. ★ MAIDSTONE DISTRICT BRANCH : Technical College, Maidstone, "Development of 'Off-Peak Heating,' with Particular Reference to Floor Warming," S. C. Dinenage, 6.30 p.m.

*Tues., Feb.* 2.—MEASUREMENT AND CONTROL SECTION : Savoy Place, London, W.C.2, "Development of the Formulæ of Electromagnetism in the M.K.S. System," P. Vigoureux, 5.30 p.m. ★ NORTH MIDLAND CENTRE : Leeds and County Conservative Club, South Parade, Leeds, 1, "Turbo-Generator Performance under Exceptional Operating Conditions," T. H. Mason, P. D. Aylett and F. H. Birch, 6.30 p.m. ★ NORTH WESTERN CENTRE : Engineers' Club, Manchester, "Digital Computer Developments at Manchester University," T. Kilburn, 6.15 p.m. ★ SOUTH-EAST SCOTLAND SUB-CENTRE : Carlton Hotel, North Bridge, Edinburgh, "Electro-Precipitators—Some Design and Operating Problems," J. E. Sayers, 7 p.m.

*Wed., Feb.* 3.—EAST ANGLIAN SUB-CENTRE : Assembly House, Norwich, "Silicone Electrical Insulation," J. H. Davis, 7.30 p.m. ★ NORTH-EASTERN CENTRE : Conservative Club, Newcastle upon Tyne, "An Outline of Television Studio Lighting Problems," R. W. Koplick, 7 p.m. ★ TEES-SIDE SUB-CENTRE : Cleveland Scientific and Technical Institution, Middlesbrough, Second Hunter Memorial Lecture, "The Protection of Electrical Systems," H. G. Bell, 6.30 p.m. ★ SOUTH-WEST SCOTLAND SUB-CENTRE : Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, "Electrical Supplies to Power Station Auxiliaries," D. A. Dewison, 6 p.m. ★ RUGBY SUB-CENTRE : College of Technology and Arts, Rugby, "Radio Aspects of the International Geophysical Year," R. L. Smith-Rose, 6.30 p.m.

*Thurs., Feb.* 4.—ORDINARY MEETING : Savoy Place, London, W.C.2, "The Shielding of Overhead Lines Against Lightning," J. H. Gridley, 5.30 p.m.

*Fri., Feb.* 5.—MEDICAL ELECTRONICS DISCUSSION GROUP : Savoy Place, London, W.C.2, Discussion on "Computers in Medical Use," opened by R. A. Buckingham, and J. M. Tanner, 6 p.m.

### INSTITUTION OF ENGINEERING DESIGNERS

*Wed., Feb.* 3.—MIDLANDS BRANCH : Queens Hotel, Birmingham, "Hydraulics," 7 p.m.

### INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

*Tues., Feb.* 2.—HUGH MACMILLAN MEMORIAL LECTURE : 39, Elmbank Crescent, Glasgow, "Radio Astronomy and the Structure of the Universe," A. C. B. Lovell, 6.30 p.m.

### INSTITUTION OF HIGHWAY ENGINEERS

*Wed., Feb.* 3.—EAST ANGLIAN BRANCH : Assembly House, Theatre Street, Norwich, "Highway Law," D. E. H. James, 6.45 p.m.

*Thurs., Feb.* 4.—YORKSHIRE AND LINCOLNSHIRE BRANCH : Adelphi Hotel, Micklegate, "The London to Yorkshire Motorway," 7 p.m.

*Fri., Feb.* 5.—LONDON BRANCH : Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, "Some Modern Developments in Highway Bridge Design," C. S. Chettoe, 5.30 p.m.

### INSTITUTION OF MECHANICAL ENGINEERS

*Sat., Jan.* 30.—EAST MIDLANDS GRADUATES' SECTION : Visit to Worthington-Simpson, Ltd., Lowfield Works, Newark, 10 a.m.

*Tues., Feb.* 2.—INTERNAL COMBUSTION ENGINE GROUP : 1, Birdcage Walk, Westminster, London, S.W.1, Discussion on "Engine Governors," 6 p.m. ★ MIDLAND BRANCH : College of Technology and Arts, Rugby, "The Design and Construction of Power Station Feed Heaters," J. V. Bigg, 6.30 p.m.

*Wed., Feb.* 3.—ORDINARY MEETING IN CONJUNCTION WITH THE HYDRAULICS GROUP : 1, Birdcage Walk, Westminster, London, S.W.1, "The Development of Some Unconventional Centrifugal Pumps," U. M. Barske, 6 p.m. ★ YORKSHIRE BRANCH : The University, St. George's Square, Sheffield, "Rubber Mountings and Springs for Industrial Applications," M. Horowitz, 6.30 p.m. ★ EASTERN GRADUATES' SECTION : Cambridgeshire Technical College and School of Art, Collier Road, Cambridge, Film Show, 7.30 p.m. ★ WESTERN GRADUATES' SECTION : All-day visit to the Steel Company of Wales, Port Talbot. ★ EAST MIDLANDS BRANCH : Royal Hotel, Grimsby, "Flash Evaporators for the Distillation of Sea Water," A. Frankel, 7.30 p.m.

*Thurs., Feb.* 4.—EASTERN BRANCH : Clarendon Laboratory, Parks Road, Oxford, Repetition of the Crompton-Lanchester Lecture, "The Structure of the Automobile," M. Platt, 7.30 p.m. ★ EASTERN BRANCH : Diocesan Hall, Ipswich, "Land Out of the Sea," K. A. Brazlen, 7.30 p.m. ★ SCOTTISH BRANCH : Royal College of Science and Technology, Glasgow, "The Importance of Biomechanics as a Service to Man," J. M. Zarek, 7.30 p.m. ★ EAST MIDLANDS GRADUATES' SECTION : College of Technology and Commerce, Leicester, Repetition of the London Graduates Annual Lecture, "The Design and Development of Machine Tools," C. A. Sparkes, 7.15 p.m. ★ YORKSHIRE GRADUATES' SECTION : Grand Hotel, Sheffield, "Labour Management," K. Wainwright, 6.30 p.m.

*Fri., Feb.* 5.—SCOTTISH BRANCH : Technical College, Dundee, "The Importance of Biomechanics as a Service to Man," J. M. Zarek, 7.30 p.m. ★ NORTH WESTERN GRADUATES' SECTION : Visit to Dunlop Rubber Company, Ltd., Cambridge Street, Manchester, 6.15 p.m.

### INSTITUTION OF PLANT ENGINEERS

*Tues., Feb.* 2.—Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2, "The Potentialities of Nuclear Power," P. T. Fletcher, 7 p.m. ★ EDINBURGH BRANCH : 25, Charlotte Square, Edinburgh, "Leith Fertiliser Works," G. B. White, 7 p.m. ★ PETERBOROUGH BRANCH : White Lion Hotel, Church Street, Peterborough, "Industrial Metering," 7.30 p.m.

### INSTITUTION OF PRODUCTION ENGINEERS

*Wed., Feb.* 3.—SCOTTISH REGION : Royal Hotel, Union Street, Dundee, "Some Aspects on Tool Design of Thermo Setting and Thermo Plastic Moulding," A. G. Elwell, 7.30 p.m.

### INSTITUTION OF THE RUBBER INDUSTRY

*Mon., Feb.* 1.—BURTON-ON-TRENT SECTION : Midland Hotel, Burton-on-Trent, "Ageing and Weathering of Rubbers and Some Plastics," W. Mc.G. Morgan, 7.30 p.m. ★ NORTH EASTERN SECTION : Eldon Grill, Grey Street, Newcastle, Short papers evening and discussion, 7 p.m. ★ SOUTH WALES AND MONMOUTHSHIRE SECTION : Royal Hotel, Cardiff, "Bonding Systems," W. A. Gurney, 7.30 p.m.

*Thurs., Feb.* 4.—SOUTHERN SECTION : The University, Southampton, "Plastics and Rubbers under Extreme Operating Conditions," E. W. Russell, 7.30 p.m.

### JUNIOR INSTITUTION OF ENGINEERS

*To-day, Jan.* 29.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Ceramics," A. Dinsdale, 7 p.m.

*Wed., Feb.* 3.—MIDLAND SECTION : James Watt Memorial Institute, Great Charles Street, Birmingham, "The New Motorways," T. MacMillan, 7 p.m.

*Fri., Feb.* 5.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, Films, "Building with Straw," "Electric Water Heating Installation Practice," and "No Rust Here," 7 p.m.

### MANCHESTER ASSOCIATION OF ENGINEERS

*To-day, Jan.* 29.—Engineers' Club, Albert Square, Manchester, 2, "The Development and Application of Lightweight Sandwich Structure," H. R. Ashley, 6.45 p.m.

### NEWCOMEN SOCIETY

*Wed., Feb.* 3.—Science Museum, London, S.W.7, "The Boat Store, Sheerness, 1859-60," A. W. Skempton, 5.30 p.m.

### PLASTICS INSTITUTE

*Tues., Feb.* 2.—LONDON AND DISTRICT SECTION : Wellcome Building, 183-193, Euston Road, London, N.W.1, Symposium on "Preplasticising in Injection Moulding," 4 p.m.

*Thurs., Feb.* 4.—SOUTHERN SECTION : Chemistry Department, The University, Southampton, "Plastics and Rubbers under Extreme Operating Conditions," E. W. Russell, 7.30 p.m.

### REINFORCED CONCRETE ASSOCIATION

*Tues., Feb.* 2.—NORTH-WESTERN BRANCH : College of Technology, Sackville Street, Manchester, "The Joint Problem in Precast Reinforced Concrete Structures," J. A. Derrington, 6.45 p.m. ★ MIDLAND COUNTIES BRANCH : Birmingham and Midland Institute, Paradise Street, Birmingham, "The Design and Construction of the Plymouth Market Hall," A. P. Mason, 6 p.m.

*Wed., Feb.* 3.—NORTH WESTERN BRANCH : Liverpool Engineering Society, The Temple, 24, Dale Street, Liverpool, "The Joint Problem in Precast Reinforced Concrete Structures," J. A. Derrington, 6.30 p.m.

### ROYAL INSTITUTION OF CHARTERED SURVEYORS

*Mon., Feb.* 1.—ORDINARY GENERAL MEETING : 12, Great George Street, Westminster, London, S.W.1, "High Buildings," R. H. Matthew, 5.45 p.m.

### ROYAL METEOROLOGICAL SOCIETY

*To-day, Jan.* 29.—SCOTTISH CENTRE : Department of Natural Philosophy, Drummond Street, Edinburgh, "Some Meteorological Aspects of Air Pollution," P. J. Meade, 5 p.m.

### ROYAL INSTITUTION OF NAVAL ARCHITECTS

*Thurs., Feb.* 4.—10, Upper Belgrave Street, London, S.W.1, "Full Scale Tank Tests of an International 10 square metre Class Canoe"; "The Geometry of Sailing to Windward," T. Tanner, and "The Behaviour of the Sailing Yacht," H. M. Barkla, 4.45 p.m.

### ROYAL SOCIETY

*Thurs., Feb.* 4.—Burlington House, Piccadilly, London, W.1, Discussion on "The Results of The Royal Society I.G.Y. Expedition," opened by Sir Graham Sutton, 10.30 a.m.

### SOCIETY OF CHEMICAL INDUSTRY

*Fri., Feb.* 5.—FIFTH IVAN LEVINSTEIN MEMORIAL LECTURE : Large Chemistry Theatre, The University, Oxford Road, Manchester, "The Future of Chemicals from Petroleum," L. H. Williams, 6.30 p.m.

### SOCIETY OF ENGINEERS

*Mon., Feb.* 1.—Geological Society, Burlington House, Piccadilly, London, W.1, Presidential Address, E. G. Massy Collier, 5 p.m.

## Advanced Engineering Courses

**Management Practice and the System Analyst.** MANAGEMENT TRAINING (P.E.), Ltd., TRAINING DIVISION OF PRODUCTION-ENGINEERING, Ltd., 12, Grosvenor Place, London, S.W.1. A six-week course, beginning on February 1, in using computers. Five main subjects will be covered : (1) Management Organisation and the Control of Production ; (2) The Analytical Study of Work ; (3) Financial and Management Accounting ; (4) Office Administration ; (5) Computers and their Associated Problems. Nominations should be sent to the Course Secretary, Management Training (P.E.), Ltd., Park House, Wick Road, Egham, Surrey. Fee 185 guineas (non-residential).

**Some Basic Engineering Problems in Tidal Estuaries.** UNIVERSITY OF LONDON, Senate House, Russell Square, London, W.C.1. A course of three lectures by Professor A. T. Ippen, "Tide-dynamics in Estuaries," "Diffusion and Energy Dissipation in Estuaries," and "Sediment Problems in Estuaries." February 8, 10 and 12, at 5.30 p.m. Admission free.

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| 2" dia. | Oil quenched 830°C. Oil quenched 760°C. tempered 180°C. | 82·1 | 17·5 | 61 |
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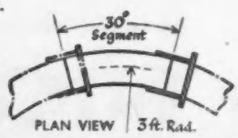


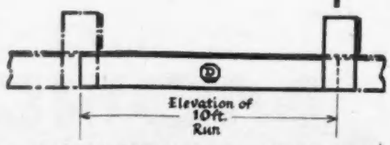


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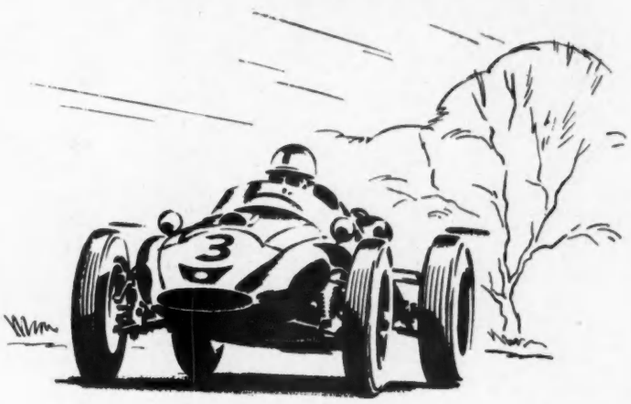

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**"Stone's Magnesium Castings were chosen because they give the most strength for the least weight"... say Coopers.** Many developments in the motoring, aeroplane, electronic and other industries have been facilitated by consultation with J. Stone of Charlton. From the wealth of their experience in the production of sand, die and precision castings in aluminium, magnesium and copper base alloys, J. Stone are often able to offer advice resulting in both technical and economic advantages.

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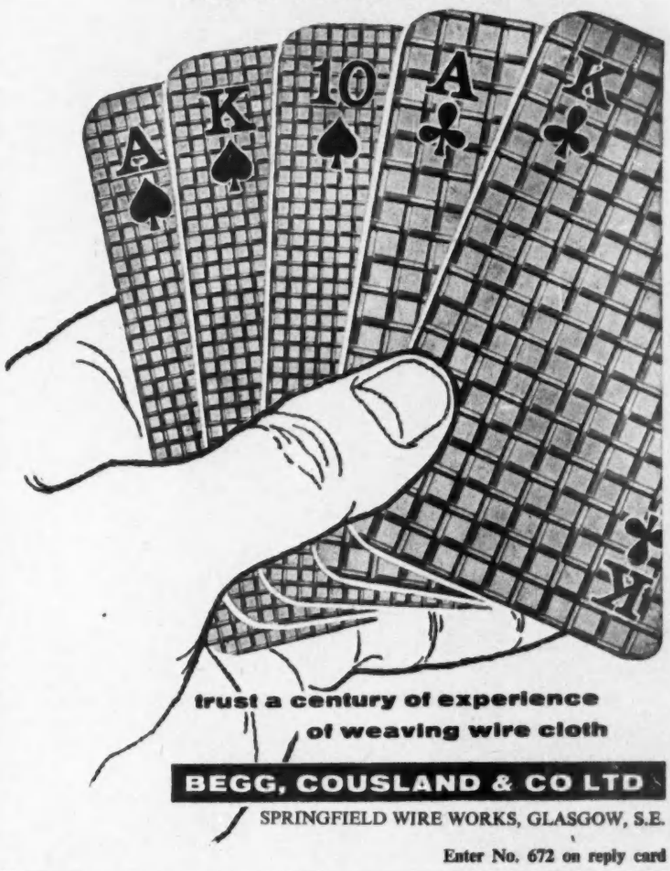


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*says Will the Welder*

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The clockwork machine which turns a hand cutter into a precision machine cutter. Ideal for flame cutting on site.

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An Automatic dual-purpose machine for all kinds of cutting work.

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Suffolk Iron Foundry (1920) Ltd., Stowmarket, Suffolk.

*Please send me leaflets detailing Sifbronze equipment.*

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. . . and the results of his work give excellent performance.

For, whatever casting process is required for *your* production—cement-sand, shell-moulding or 'lost-wax'—the team of experts at David Brown Foundries Division carries it out with supreme skill and care.

There is no proven method of casting that is not within the scope of the division's resources. There is no recognised technique of testing that is not used at Penistone. Inspection by X- and gamma-radiography, by photo-electric absorptiometer and by spectrograph, are standard. Electromagnetic flaw detection is applied to all steel castings for aircraft and other special applications.

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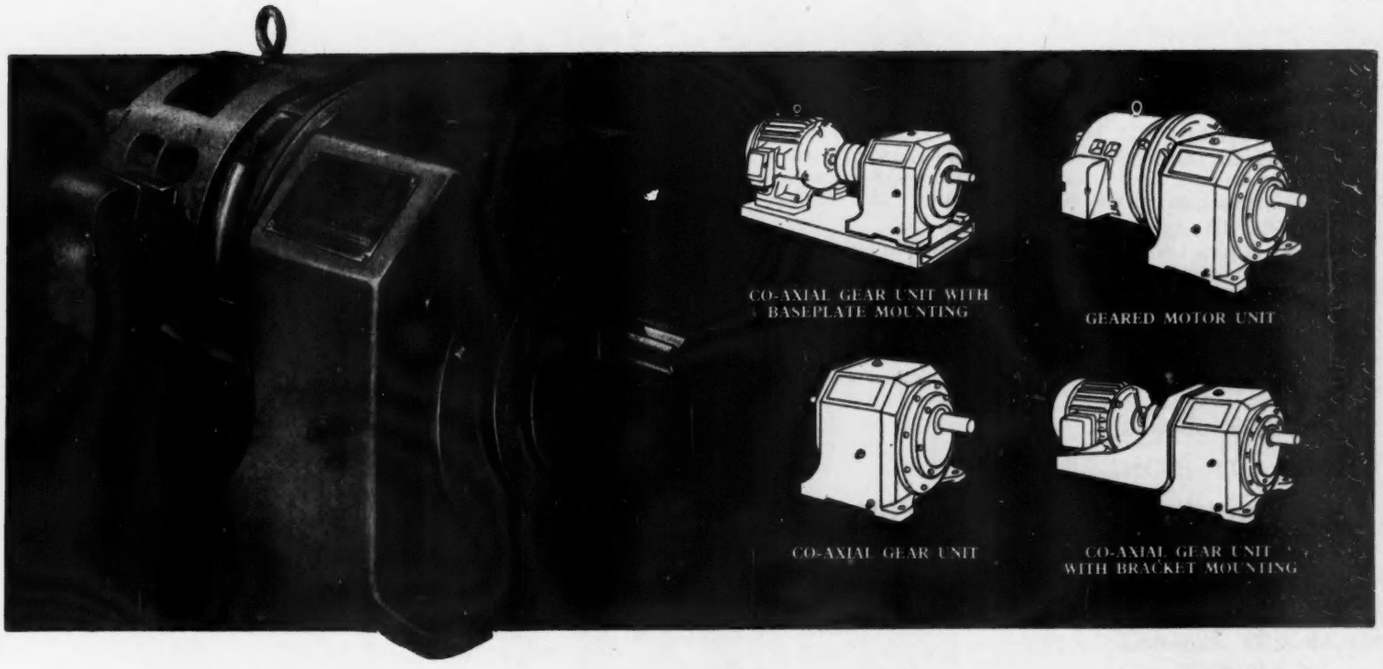
CO-AXIAL GEAR UNIT WITH BASEPLATE MOUNTING
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Helicon geared motors and co-axial geared units are new . . . and all the better for being made by David Brown, the firm with 100 years' experience of gears. That means greater accuracy more reliability with less maintenance — in fact a quiet, compact, sturdy, quality product.

There is a booklet No. F. 444.3 waiting for you. It tells about the range of units covering 34 standard ratios for any drive up to 40 h.p. Write for it to-day.

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geared motors and co-axial geared units

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Mushet Special "VG" high-speed steel is the very latest development of tool steels in the United Kingdom, by Samuel Osborn & Co., Limited. Remarkable results under production conditions are assured, far in advance of other tool steels in this category.

Stocks of lathe tools, planer tools and toolholder bits, in this steel, are available in standard sizes.

***IMPROVED PERFORMANCE FROM MACHINE TOOLS***

If you use centre lathes, capstans, automatics, combinations, planers, shapers, boring mills, etc., these tools will :

★ **CUT FASTER**

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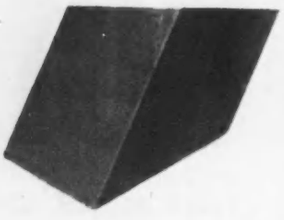
★ **MACHINE TOUGHER MATERIALS —including Nimonic alloys**

★ **REDUCE PRODUCTION COSTS**

• *ALSO AVAILABLE IN BAR AND BLANK FORM*



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*Approximately 300 tons.

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" Monarc " Electrodes were chosen for their extremely easy weldability and sound mechanical and physical properties, and are ideal for all positions of welding on site, or in the fabricating shop.

" S.S. BRITISH QUEEN " was launched on 16th September, 1959, by Her Majesty Queen Elizabeth, the Queen Mother, and was built by Messrs. John Brown & Company (Clydebank) Limited to the order of: The B.P. Tanker Company Limited.

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**IN STEEL BLACK OR MACHINED TO 24 TONS**

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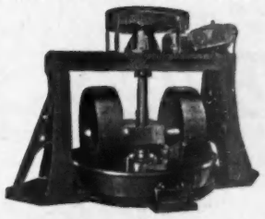

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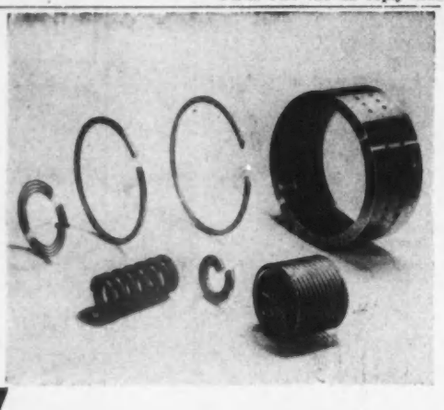

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NOT ONLY 2,500 DIFFERENT TOOLS, BUT 2,500 STOCK TOOLS. AVAILABLE IN ENGLISH, AMERICAN, UNIFIED & METRIC SIZES. MADE FROM CHROME ALLOY STEEL. SUPERBLY FINISHED.

EACH ONE THE BEST IN ITS CLASS.

**TOOL UP WITH** CHROME ALLOY STEEL BRITOOL SERVICE TOOLS

Manufactured at
BRITOOL WORKS, BUSHBURY, WOLVERHAMPTON, ENGLAND.

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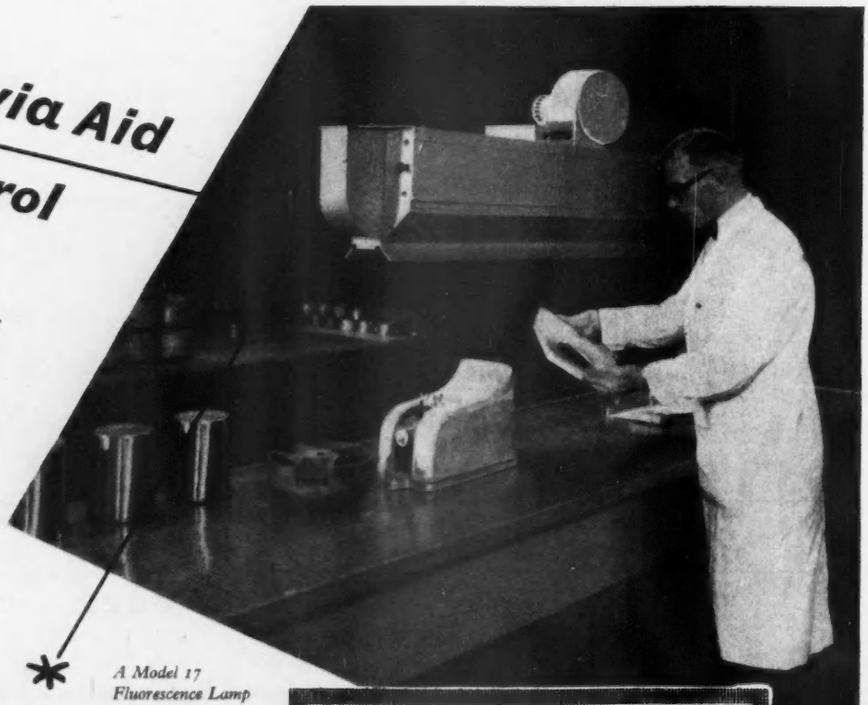
*** Another Hanovia Aid to Quality Control**

The Hanovia Model 17 Fluorescence Lamp provides the means of non-destructive testing of large engineering components by the use of fluorescent inks. The unit is suspension mounted and is of particular use for crankshaft, steel tube, steel sheet, large forgings and component inspection on a conveyor belt system. In the mining industry the Model 17 is well suited to the detection of mineral in crushed ore. Hanovia inspection lamps are also widely used in the textile, chemical, rubber and electrical industries. Please write for details.



* *A Model 17 Fluorescence Lamp being used to examine castings.*

**MODEL 16**

Model 16 is a *portable* unit for the detection of cracks and flaws and is used for practically every large engineering and assembly works (including many aircraft companies) in the U.K.

**Engelhard Industries Ltd.**

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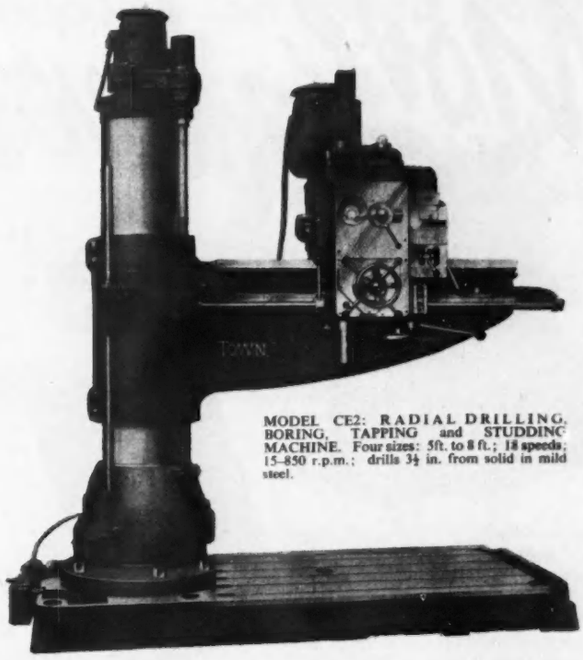
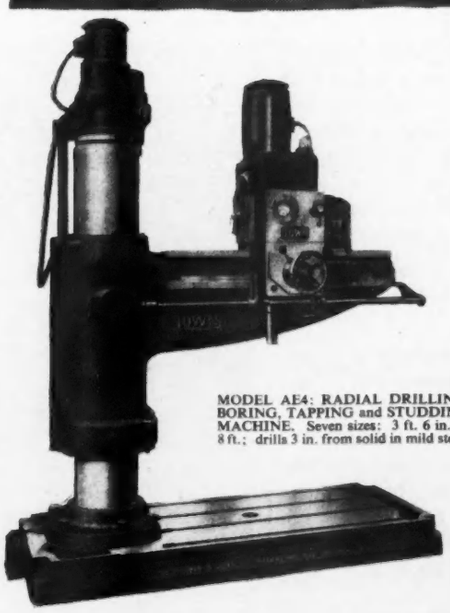
# TOWN

## DRILLING MACHINES

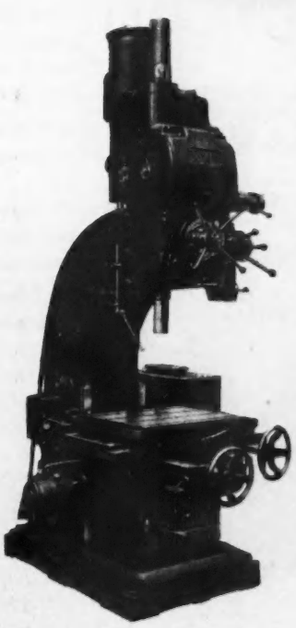
Established over 50 years, the TOWN range of radial and vertical drilling machines is noted throughout the world for modern design, reliability and ease of operation.



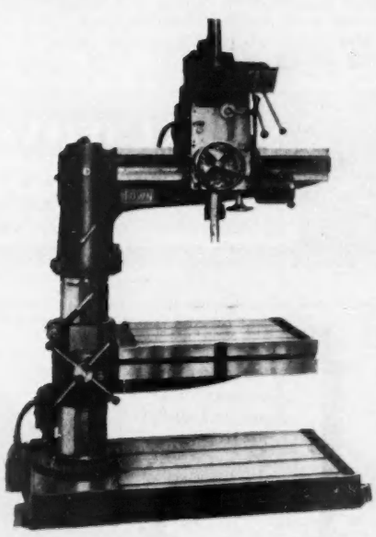
MODEL CE2: RADIAL DRILLING, BORING, TAPPING and STUDDING MACHINE. Four sizes: 5ft. to 8 ft.; 18 speeds; 15–850 r.p.m.; drills 3¼ in. from solid in mild steel.



MODEL AE4: RADIAL DRILLING, BORING, TAPPING and STUDDING MACHINE. Seven sizes: 3 ft. 6 in. to 8 ft.; drills 3 in. from solid in mild steel.



MODEL AE2: VERTICAL DRILLING MACHINE (heavy-duty model). Two sizes: 36 in. and 42 in.; drills 3¼ in. from solid in mild steel.



MODEL AE5: RADIAL DRILLING, TAPPING and STUDDING MACHINE. 42 in.; drills 1¼ in. from solid in mild steel or 1½ in. in cast iron.

MODELS EG4 and EG8: RADIAL DRILLING GIRDER MACHINES. Each model in five sizes: 4 ft. to 8 ft.; 4 speeds; 160–600 r.p.m. (EG4), 8 speeds; 20–500 r.p.m. (EG8), drills up to 2 in. from solid in mild steel. Also made with single speed.

**OTHER MACHINES IN THE RANGE**

are detailed in a folder 'GO TO TOWN' which is available on request. Variations on the standard range can be undertaken, and examples are also illustrated in the folder.

# FRED$^{K}$. TOWN & SONS LTD

ESTABLISHED · 1903

**HALIFAX · YORKS**

**PHONE: HALIFAX 60373/4**

T.1B.

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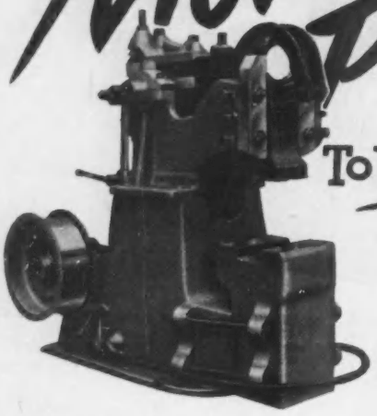

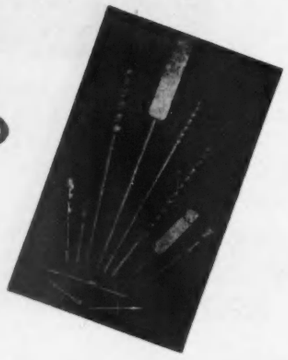

275/300 blows per minute.
Average size of work 1¾" bar.
Adjustable stroke and guides.
Rubber cushioned overhead motion.
Loose Anvil Block.
Separate motor stand available.
*A typical example of the type of work accomplished on this machine (illustrated right).*
*For High Speed Precision Forging—the Model '100' POWER HAMMER.*

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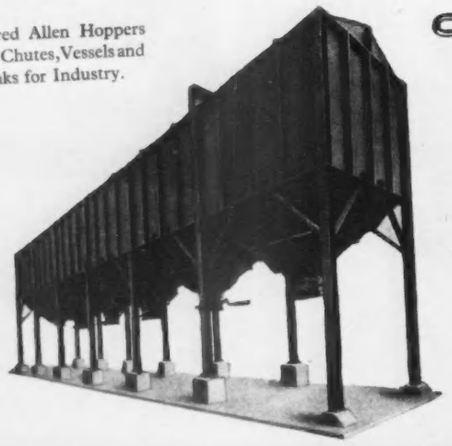

Contact Alfred Allen! They're the right people for Platework. We can rely on the accuracy and quality of their workmanship absolutely. B. D.

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## SUITABLE FOR ALL INDUSTRIAL APPLICATIONS

The "Metcalfe's" High Pressure Washing Plant provides the answer to the problem of cleaning in industry to-day. The plant is supplied on a suitable hand truck for portable use or it can be fitted as a permanent installation, and the only services required to operate it are :

(1) Water supply (static or mains). The consumption is 550 gallons per hour.

(2) Steam supply at any pressure above 60lbs. per square inch. The consumption is 700lbs. per hour.

The Washer is extremely simple to operate and can be easily operated in complete safety by unskilled personnel. The high temperature and pressure of the jet make it unequalled for power and efficiency and the use of cleaning solutions is not normally required.

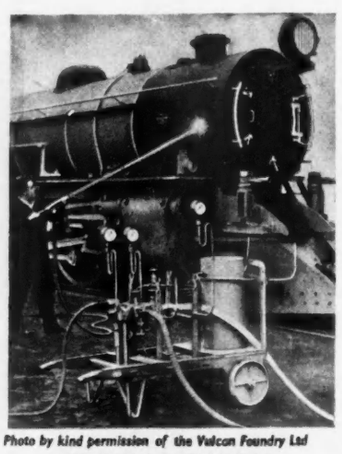

*Photo by kind permission of the Vulcan Foundry Ltd*
CLEANING A LOCOMOTIVE

CLEANING A SLAUGHTER-HOUSE FLOOR

### ADVANTAGES OF THE 'D & M' SYSTEM OF WASHING

- (1) Delivers an extremely hot supply of water at a very high pressure thus ensuring the most efficient cleaning.
- (2) Ensures a great reduction in cleaning costs, due to the saving in man hours which is always found.
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- (4) It will operate satisfactorily with low steam pressures (60lbs. per square inch upwards).
- (5) It can be operated with perfect safety and satisfaction by a non-skilled labourer.
- (6) Simple, compact and light.
- (7) No detergents or cleaning solutions are normally necessary.
- (8) No other system offers the same flexibility at low operating costs, low maintenance and low installation costs as the Metcalfe High Pressure Washing Plant.
- (9) A wide range of jet temperature and pressure is available so that the apparatus is suitable for all types of requirements.

*WRITE FOR LEAFLET S.11*

**DAVIES & METCALFE LTD**
INJECTOR WORKS · ROMILEY · MANCHESTER
*Telegrams:* EXHAUST, ROMILEY *Telephone:* WOOdley 2626 (2 lines)

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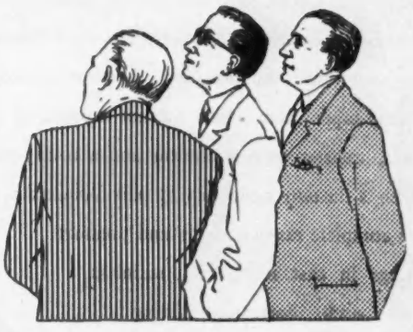
The illustrations show just a few examples of Cull craftsmanship.

All are completely hand forged. We supply hand and smithed forgings to any steel specification in the "as forged," normalised, annealed or oil hardened and tempered condition.



CULL

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Phone : MIDland 6048-9 Grams : CULANSONS, B'HAM

*Works also at:*

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*if its different then send it to "Culls"*

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# ALL-OUT SERVICE WITH KONTITE

When you specify KONTITE fittings you are assured of prompt delivery from the largest range of pipe fittings in the trade. You receive your order by return, or at the very most within a few days. You save time, labour and costs, because KONTITE fittings are designed to make highly efficient joints at the turn of a spanner. Send for the fully illustrated catalogue of KONTITE fittings.

**Plan right with KONTITE**

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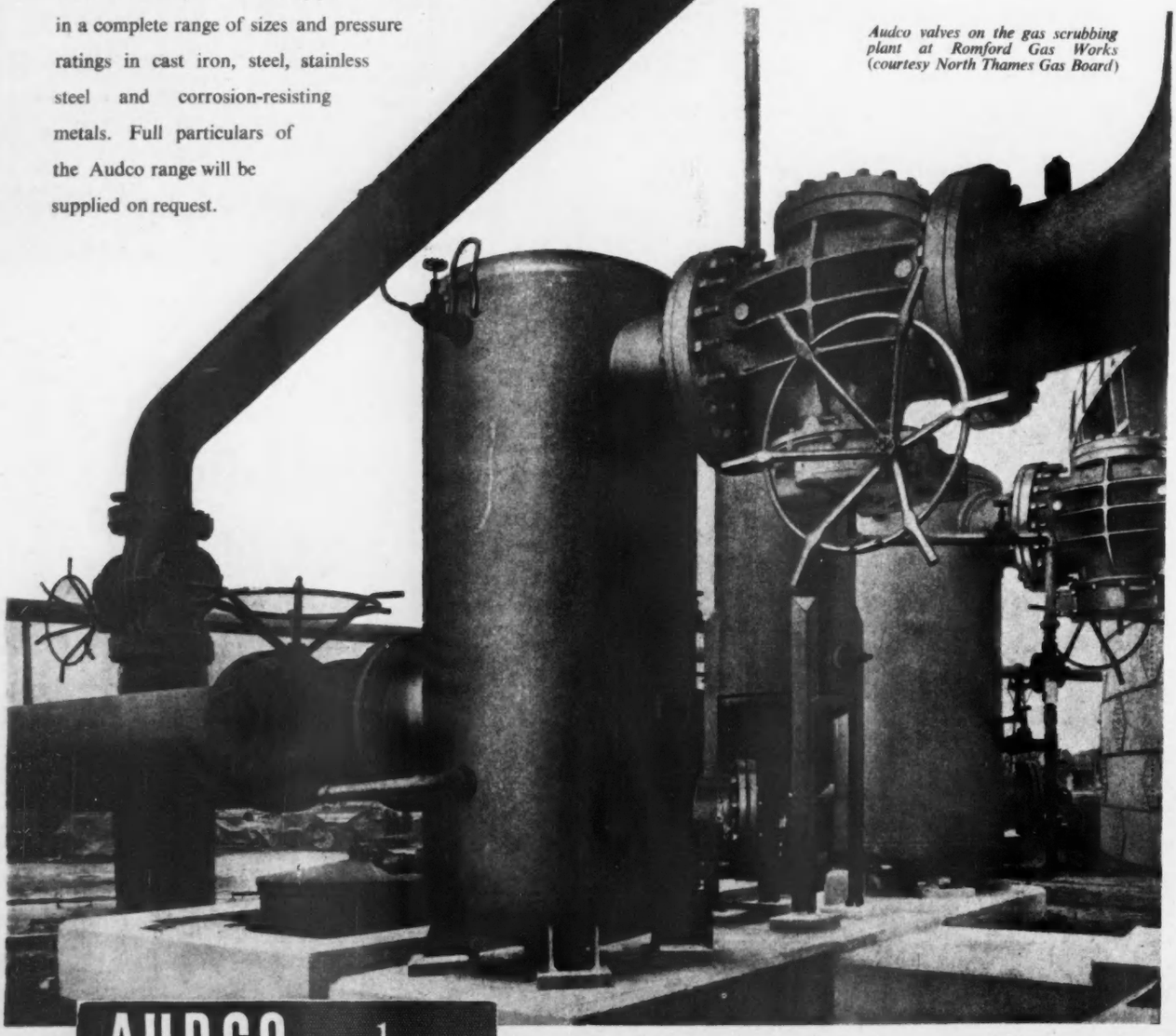
# AUDCO *valves*

**LUBRICANT SEALED FOR A POSITIVE SHUT-OFF**

Cut your maintenance costs by installing Audco lubricated plug valves . . . they cost no more than ordinary valves and cost less to maintain. A unique pressurised lubricant system provides a leak-proof seal and ensures easy rotation of the plug (without friction) under extremes of temperature and pressure . . . other economy features include taper seats which are not exposed to moving fluids, quarter turn operation and a rotary plug which is the *only* basic moving part. Available in a complete range of sizes and pressure ratings in cast iron, steel, stainless steel and corrosion-resisting metals. Full particulars of the Audco range will be supplied on request.



*Audco valves on the gas scrubbing plant at Romford Gas Works (courtesy North Thames Gas Board)*

**AUDCO valves**

**AUDLEY ENGINEERING CO. LTD., NEWPORT, SHROPSHIRE**

*Tel: Newport Shropshire 3245. Grams: Audley, Wellington Shrops. London Office: 60-61 Trafalgar Sq., W.C.2. Tel: TRAFALGAR 4401. Grams: AUDCOLON, LONDON*

**Enter No. 761 on reply card**

# Two interesting new buildings

The upper illustration shows a new valve factory at Paignton, for Standard Telephones and Cables Limited.

*Architect : J. Francis Smith, F.R.I.B.A., F.R.I.C.S., Exeter.*
*Consulting Engineer : W. E. Green, M.I.Mech.E., M.I.Plant E., A.M.I.Prod.E., A.M.B.I.M. (Standard Telephones and Cables Ltd. Project Engineer).*
*General Contractors : Staverton Builders Ltd., Totnes.*

Below it is shown the new Middlesbrough General Hospital Accident Wing which embodies some of the most up-to-date hospital equipment.

*Architect : P. H. Knighton, M.B.E., A.R.I.B.A., Newcastle.*
*General Contractors : F. Shepherd & Son Ltd., York.*

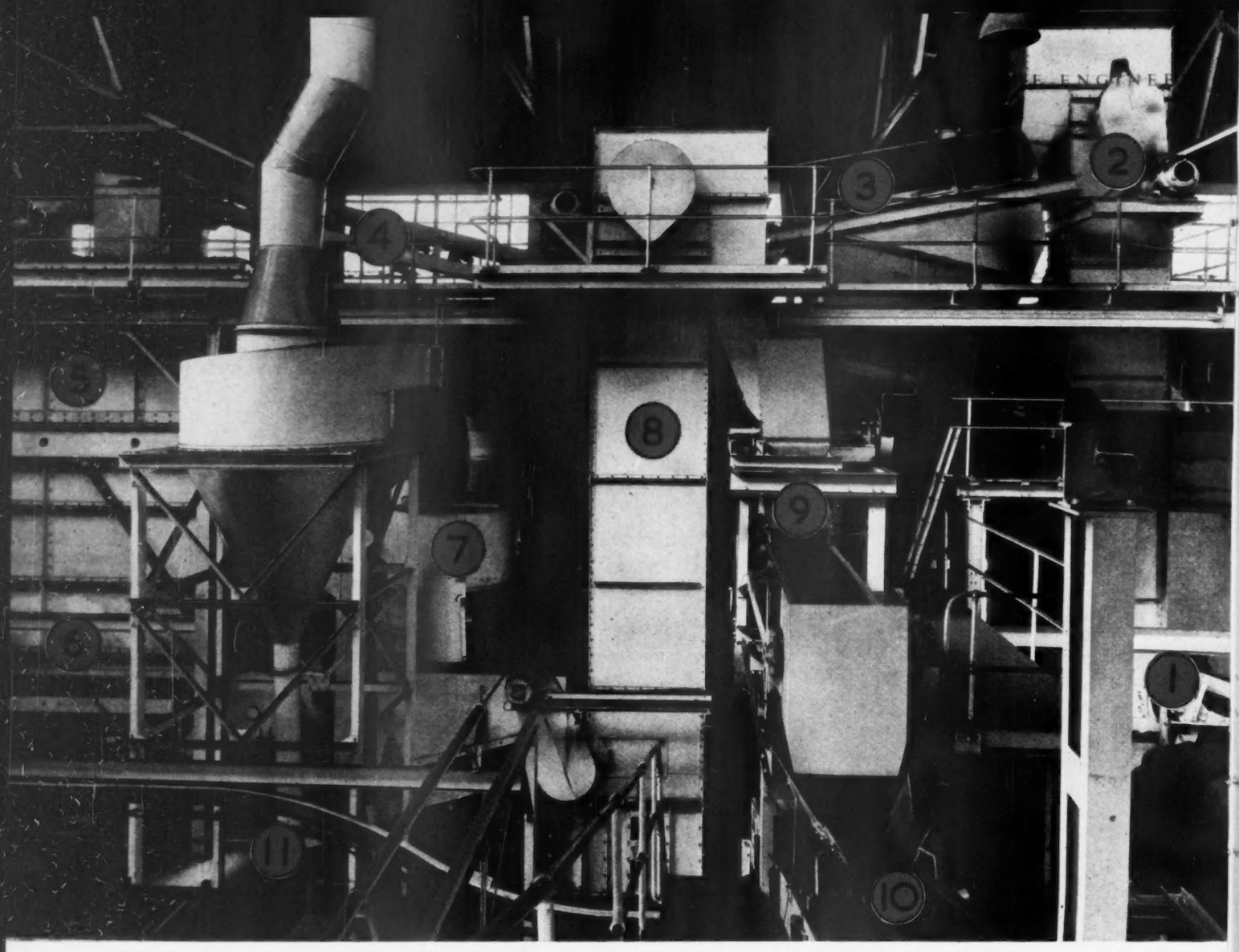
BOTH OF THESE BUILDINGS ARE BUILT WITH STEELWORK FABRICATED AND ERECTED BY

# DORMAN LONG

DORMAN LONG (Bridge & Engineering) LTD. DORMAN LONG (Steel) LTD.

BRANCHES AND AGENCIES THROUGHOUT THE WORLD

**STEELWORK IS CHEAPER AND READILY AVAILABLE**




The illustration shows that part of a **MORRIS** foundry sand and mechanization plant which reconditions knocked-out sand. At **1**, sand coming from the knock-out via an apron plate and belt conveyor passes beneath a magnetic separator (to remove tramp iron) and falls into the boot of a belt-bucket elevator **2**, discharging into screen **3** onto belt conveyor **4**, which in turn discharges into sixty-ton storage hopper **5**. The flat belt conveyor **6**, under the hopper, pours sand into the skip which feeds the mulling machine (known as the Speedmullor). This machine **7**, providing a rapid mulling cycle with close batch control, discharges the sand into belt-bucket elevator **8**. From thence, the sand proceeds via belt conveyors **9** and **10** to the moulders. The overhead chain conveyor **11** serves the core shop with sand and also takes the cores to the stoves and to the moulders.

# *Consult* MORRIS

## FOR COMPLETE HANDLING SCHEMES FOR ALL INDUSTRIES

**HERBERT MORRIS LTD P.O. BOX 7 LOUGHBOROUGH ENGLAND**

Telephone: Loughborough 3123

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The new Hoover Junior Cleaner Model 1334

# lubrication for life . . .

The production of bearings by the powder metallurgy process is our specialized business. Extensive technical research and development are behind every Lubrook Bearing and enable us to match them to the widening range of mechanical requirements. Powder size analysis, physical testing and extensive running-tests ensure the controlled porosity, structural strength and lubrication capacity of each bearing.

The self-lubricating quality of Lubrook Bronze Bearings overcomes the need for periodic lubrication, making them particularly suited to those less accessible friction points.

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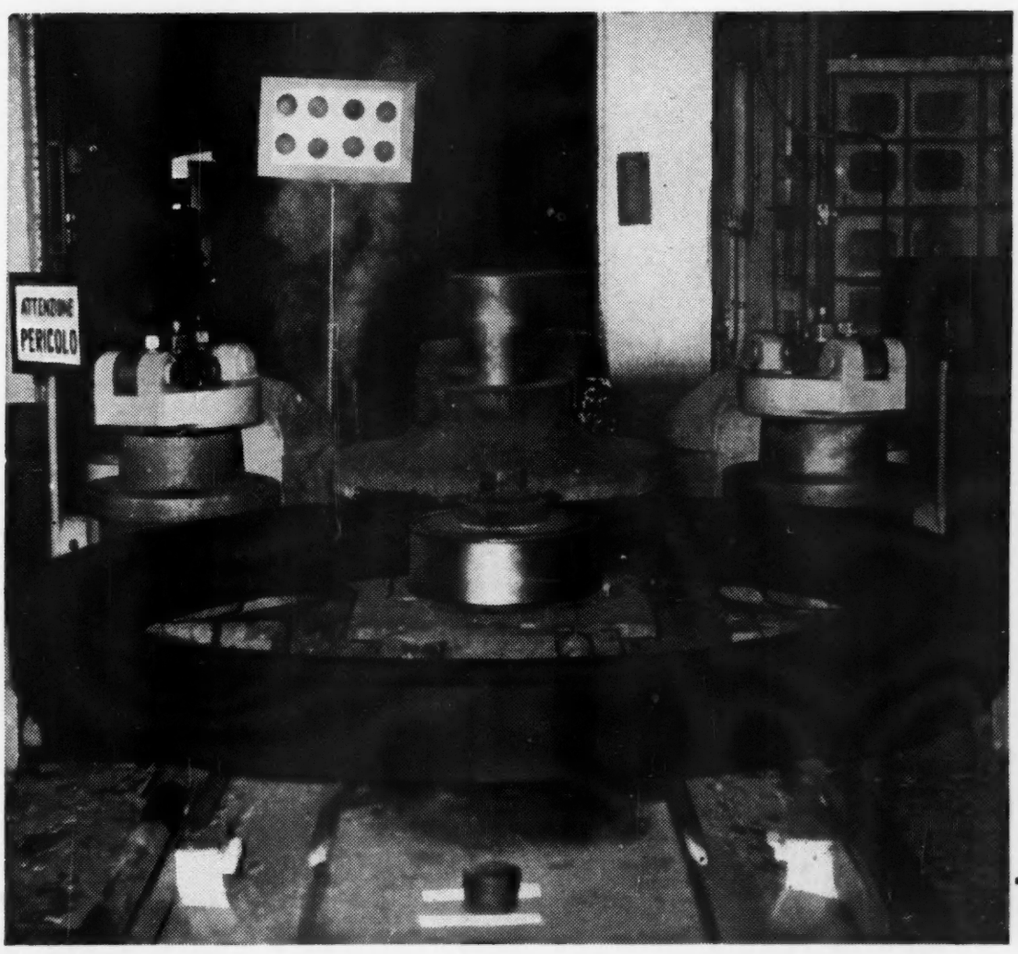


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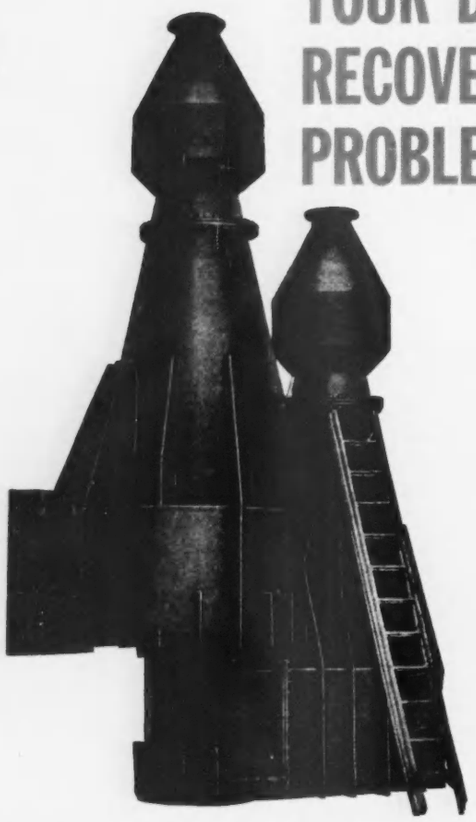

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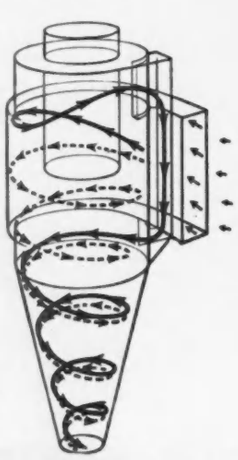

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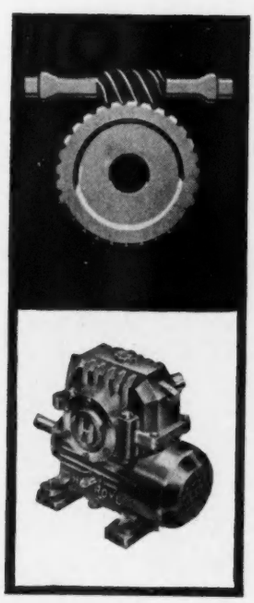



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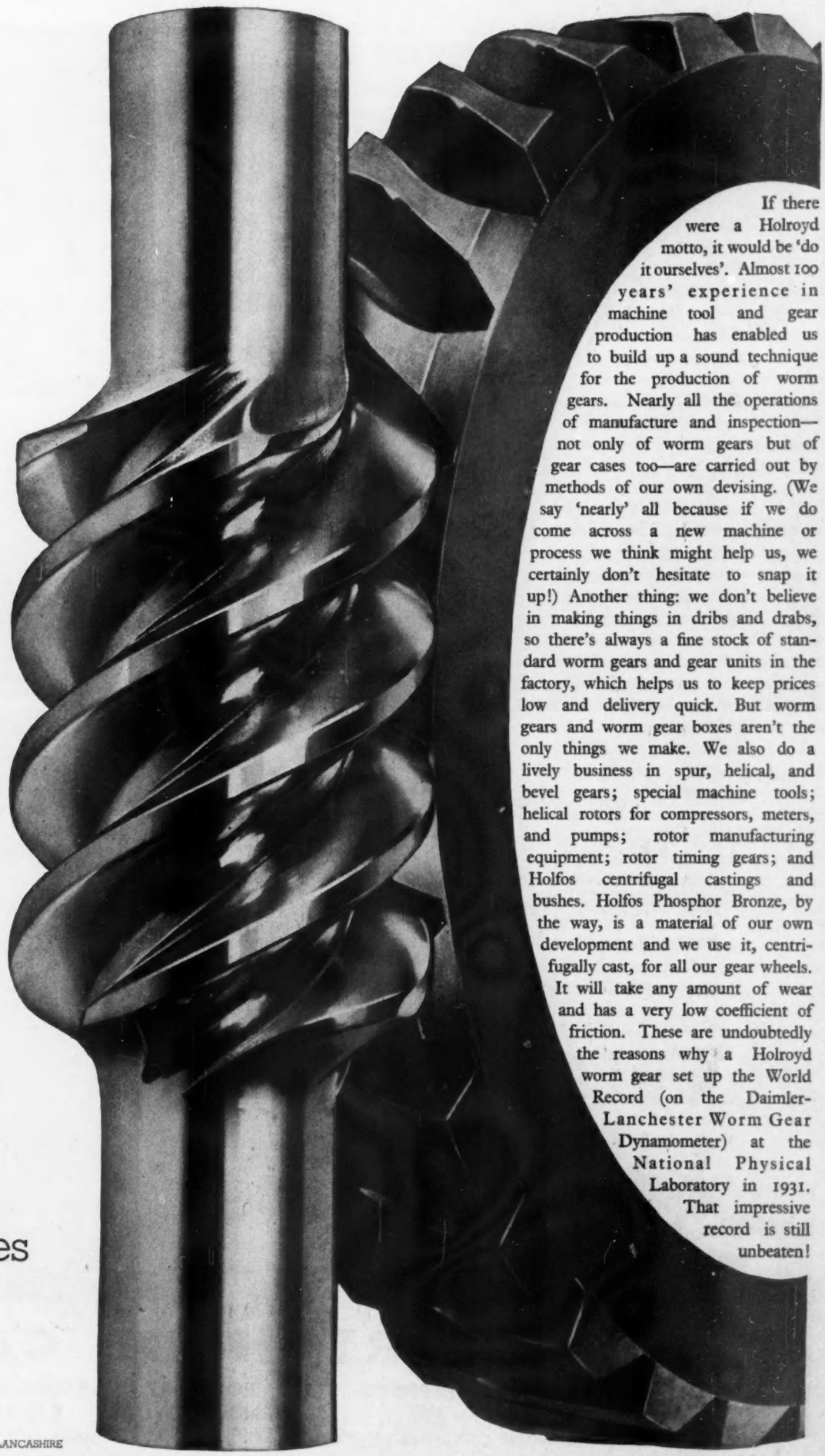

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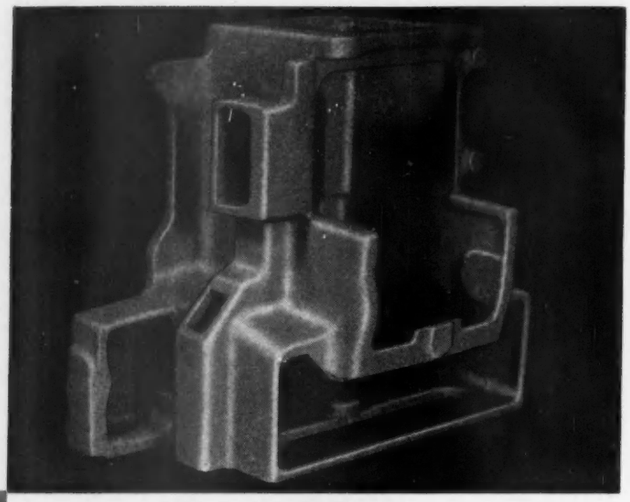

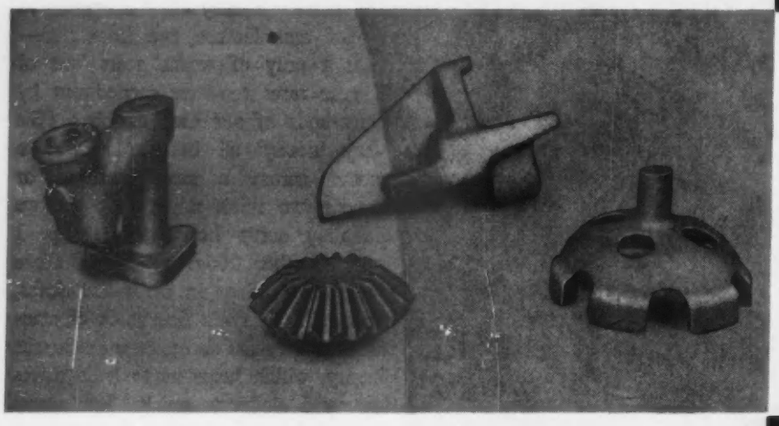

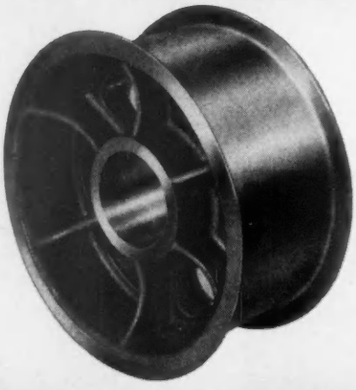

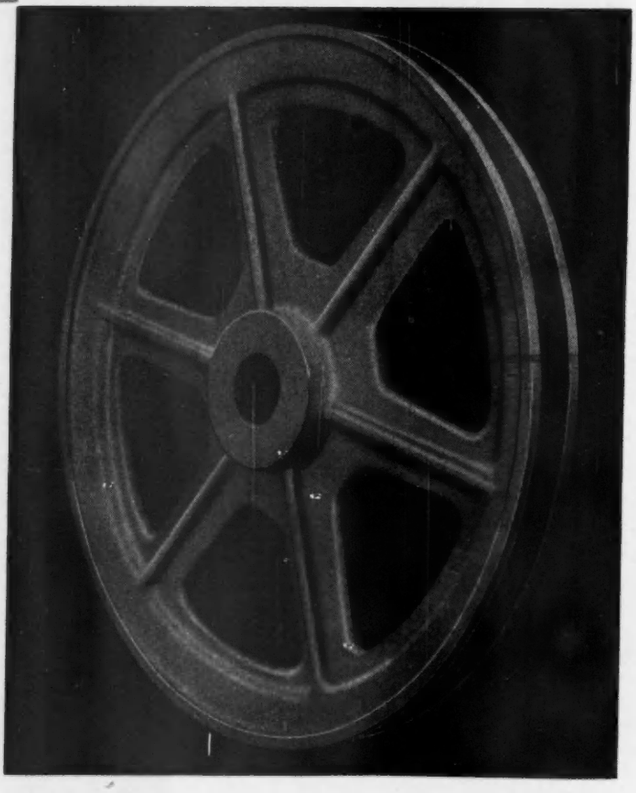

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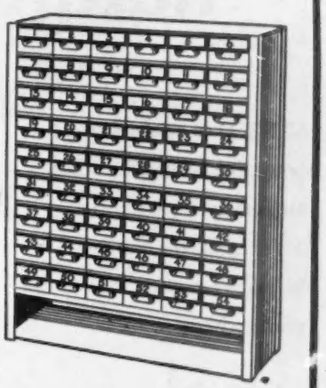

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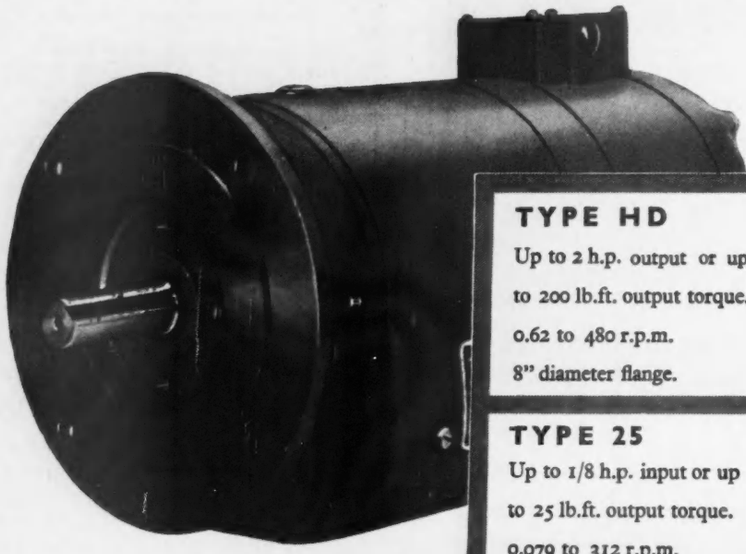

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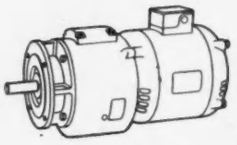

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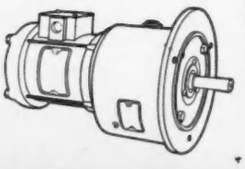

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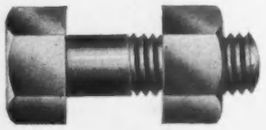
*washers*



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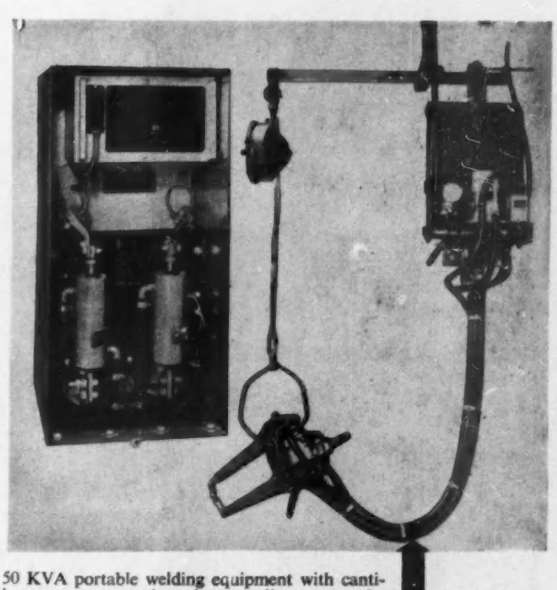

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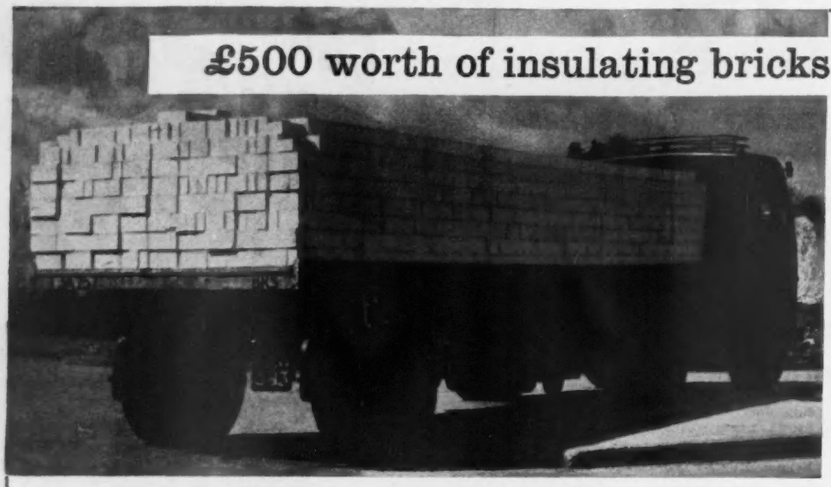

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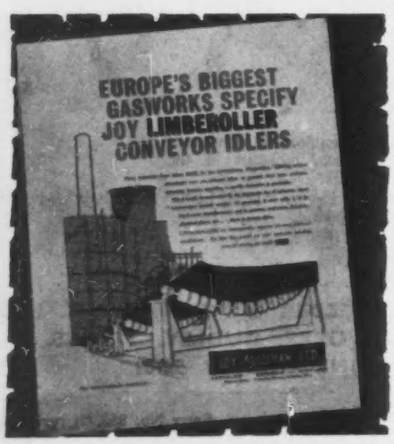


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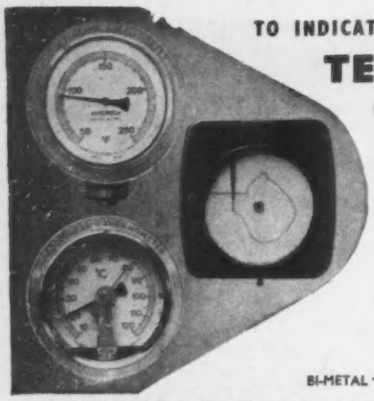

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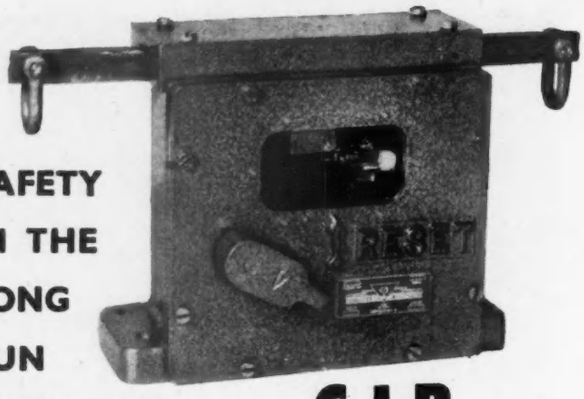

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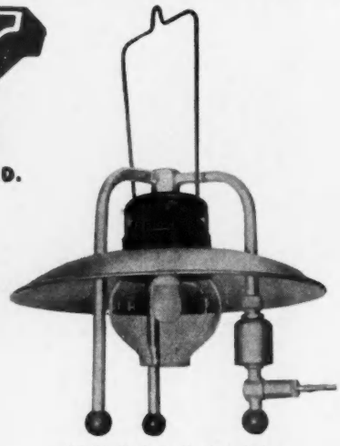

*B.T.27 Shaft or Manhole light.*

**lighting -- heating**

*B.T.25 FLOODLIGHT 10,000 M.R.C.P.*

*B.T.25 complete with Fog Filter 1712.*

*B.T.25 complete with Guard 1623.*

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We don't often blow our own trumpet. We would like to give a blast or two to introduce you to our range of lamps and heaters all operating on Propane/Butane. They are quite exceptional–but then they are designed in co-operation with the men on the job!

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*Please write for illustrated leaflets to Dept. EN.8*

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*B.T.44 Mounted on its stand No. 841*

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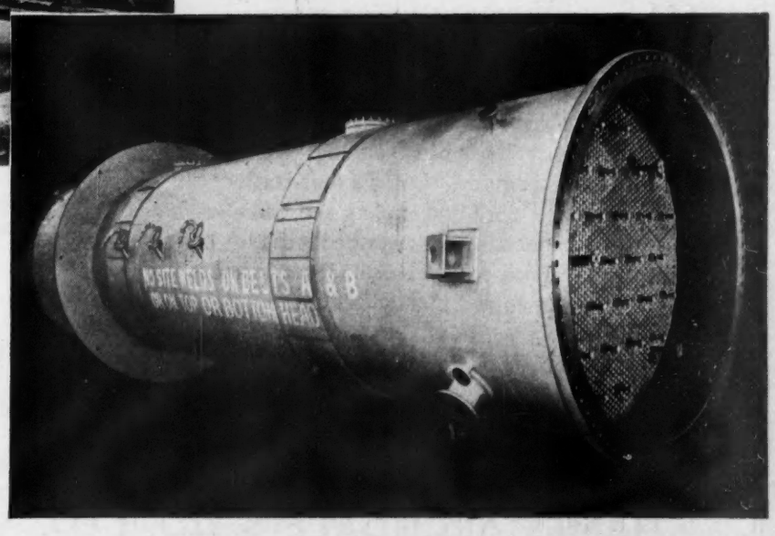
*Left:*
*A mild steel jacketed Autoclave to Class I construction with electrically driven stirring gear.*

*Below:*
*This Ethylene Oxide Reactor weighs* 135 *tons, is* 9*ft.* 6*ins. in diameter and contains over* 15 *miles of* 1¾*in. dia. catalyst tube.*



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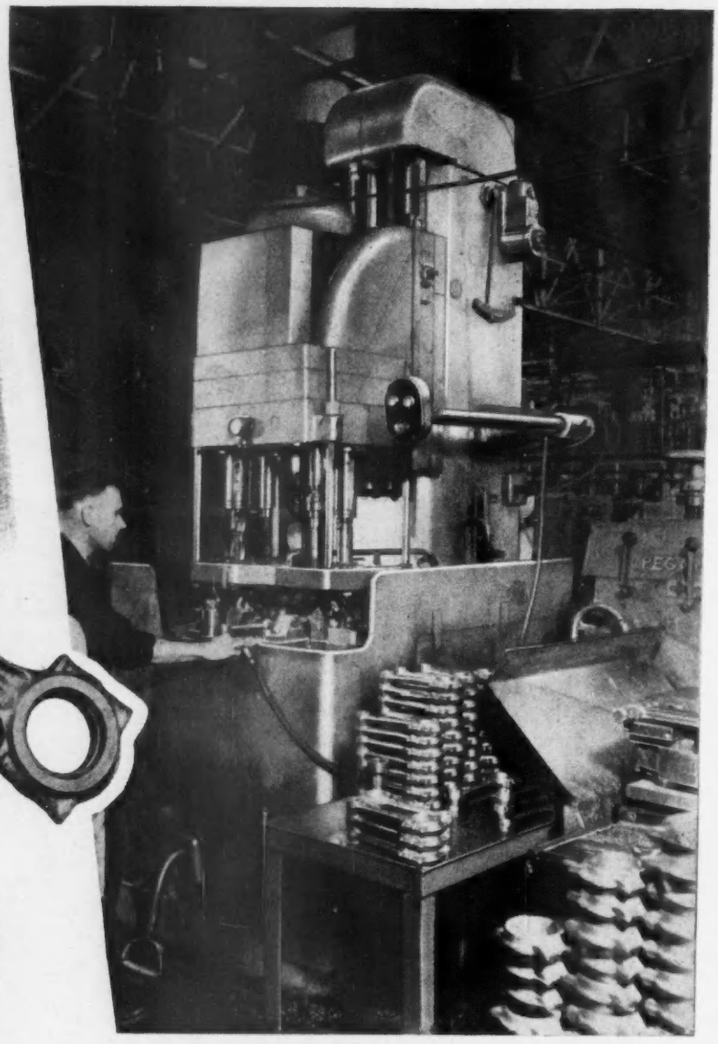

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***cuts costs on 'JAGUAR' connecting rods***

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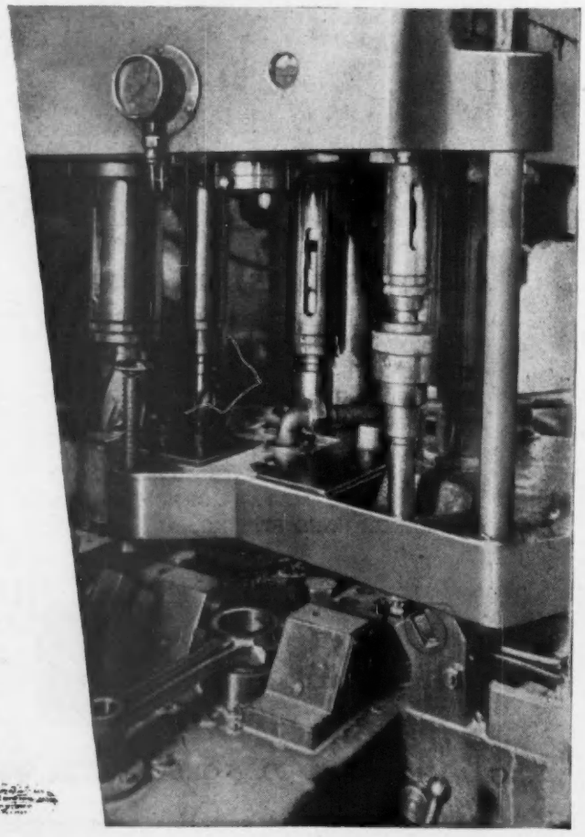

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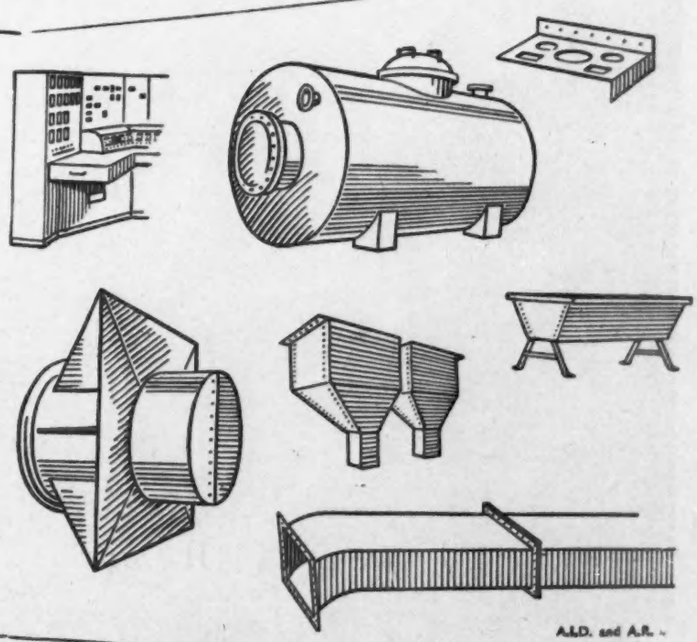

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# who is the fourth man ?

A V.I.P. certainly, not present in person but very much in spirit. A man whom the other three have probably never met and may not even know. A man who is mostly out of sight but never, never out of mind. THEY are the Acheson heads of Sales, Production and Research. HE is a customer — you, perhaps — and at this conference the man of the moment. He knows us well, otherwise he would not be present (spiritually). He knows us well, yet almost certainly not well enough. He may not realise how much more we are prepared to do to help him. He knows we were the first and are the foremost manufacturers of colloidal graphite and $MoS_2$. He knows of "Oildag" colloidal graphite in oil and "Aquadag" colloidal graphite in water. But does he know about the scores of other Acheson dispersions, of silver, lead and boron, for instance, or vermiculite, glass and mica? Does he know that we have tailor-made, to the most stringent specifications, special dispersions for the UKAEA, Government and Service departments, and many world-famous industrial concerns? If he *does* know these things we apologise for this reminder. If he doesn't, we'll leave one final point with him: there's more in the Acheson service than meets the (regular or potential) customer's eye. Naturally we would be delighted to tell him about it.

*'Oildag' and 'Aquadag' are registered trade marks of Acheson Industries (Europe) Ltd; licensed user, Acheson Colloids Limited.*

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**LIMITED**

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*Also Acheson Colloids Company, Port Huron, Michigan, U.S.A. and Acheson Colloiden N.V. Scheemda (Gr.) Netherlands*

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**HALF BRAKE DRUM SIDE**
**16' 8" DIA., 5 TONS, 12 CWTS**

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PRECISION TORQUE SPANNERS

**Sixteen models provide for loads up to 850 lbs/ft**
**Also Hydraulic Torque Generators for loads up to 3,000 lbs/ft**

★ Control torque application automatically
★ Make overloading impossible
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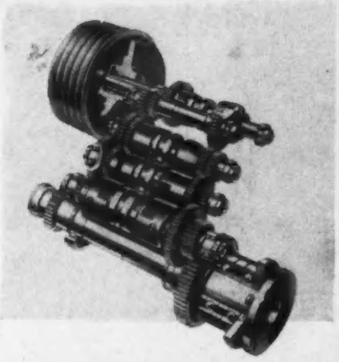
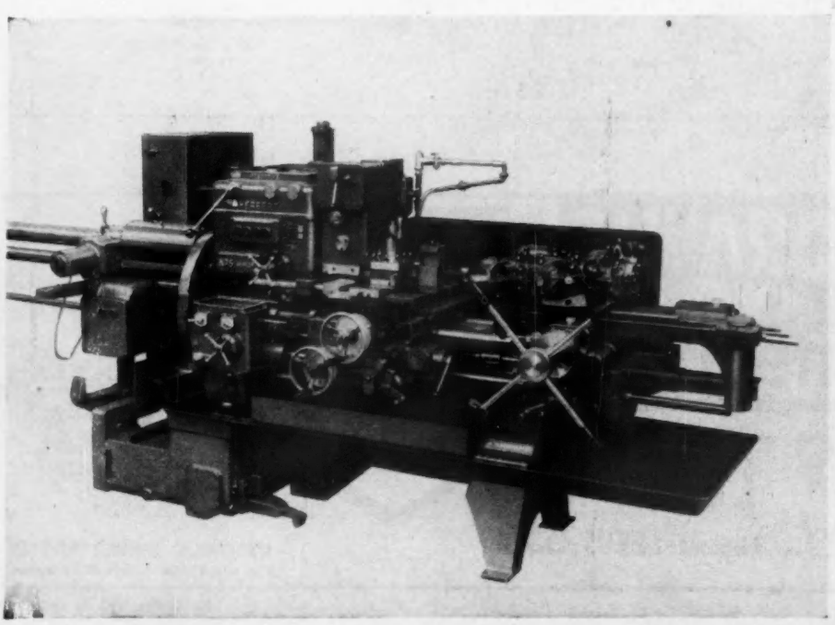


*Shaft and gearing arrangement of power-operated Preoptive headstock. Hardened and ground gears close to bearings to minimise shaft deflection. All speed changes by multi-friction clutches. Multi-vee rope drive giving high efficiency.*



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The machine incorporates all the well-known Herbert Lathe features including the power-operated Preoptive Headstock. Automatic sliding and surfacing saddle with or without chasing and taper-turning attachments. Feeds to saddle reversible independently of those to the capstan slide. Chasing mechanism, when fitted, is automatically tripped.

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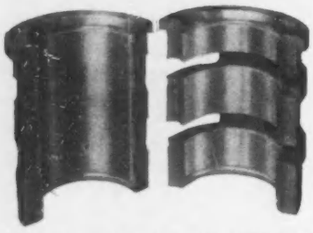

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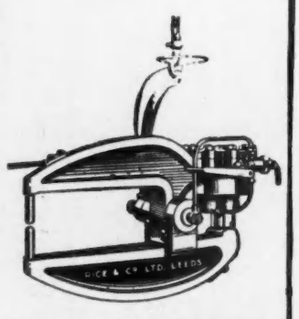

HYDRAULIC HINGED RIVETER
1'-6" to 3'-6" Gap. 20 to 30 tons power.

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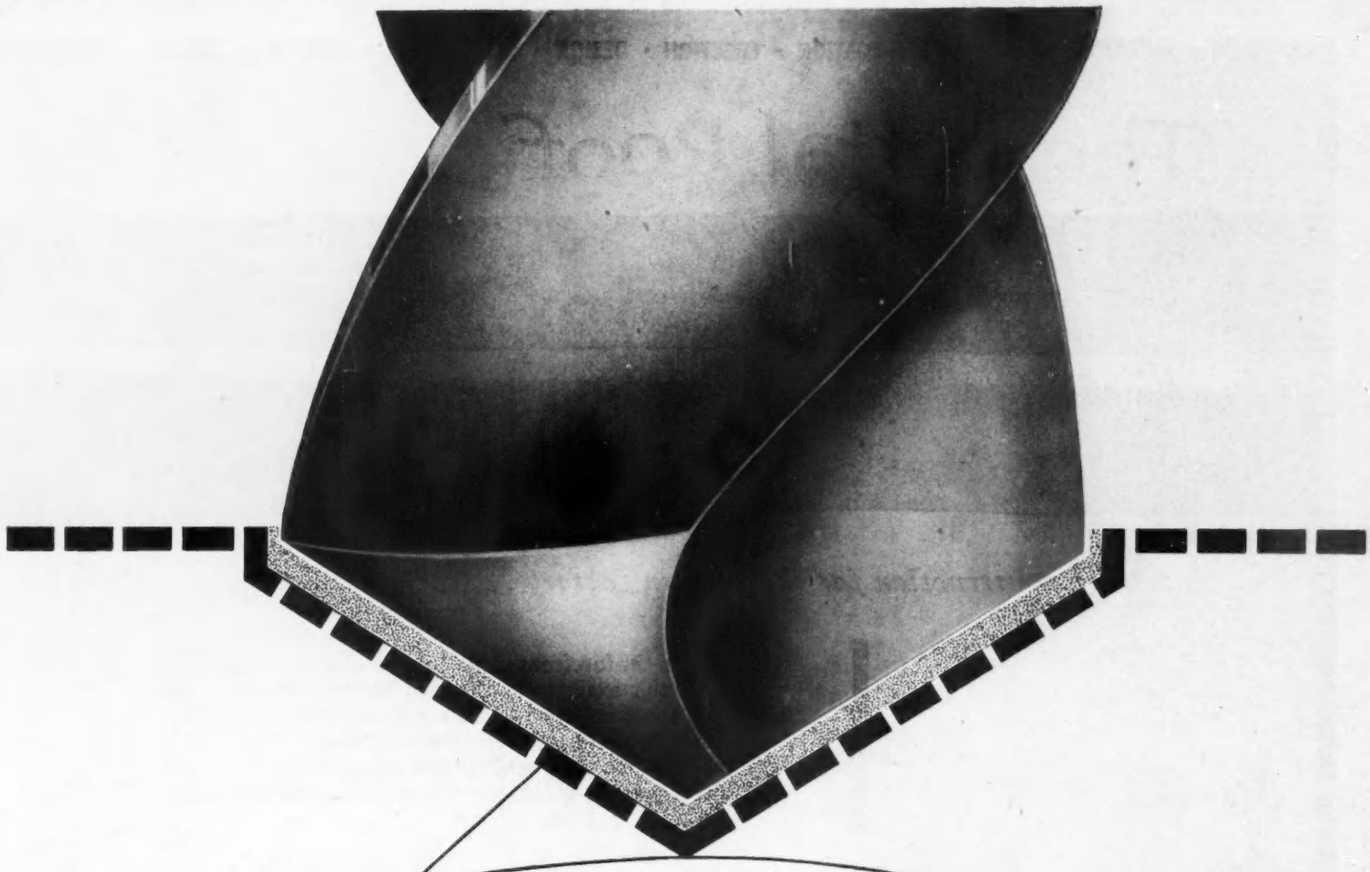

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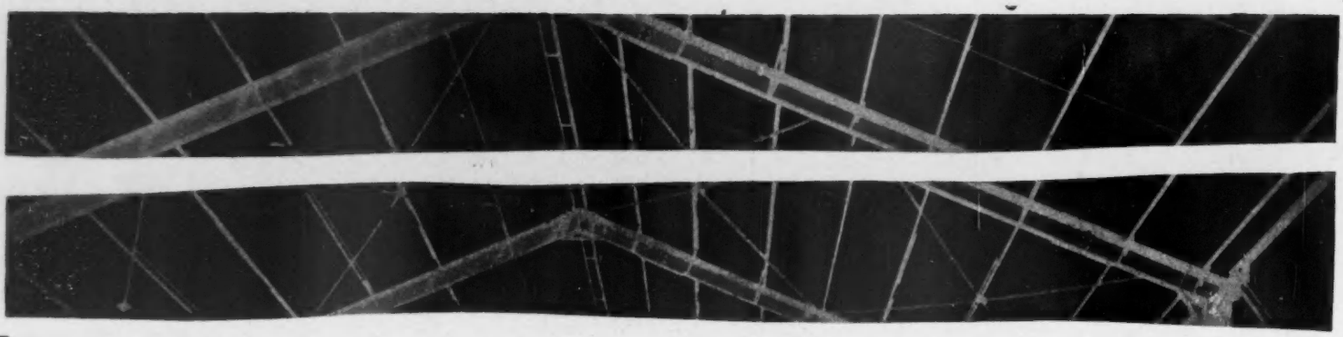
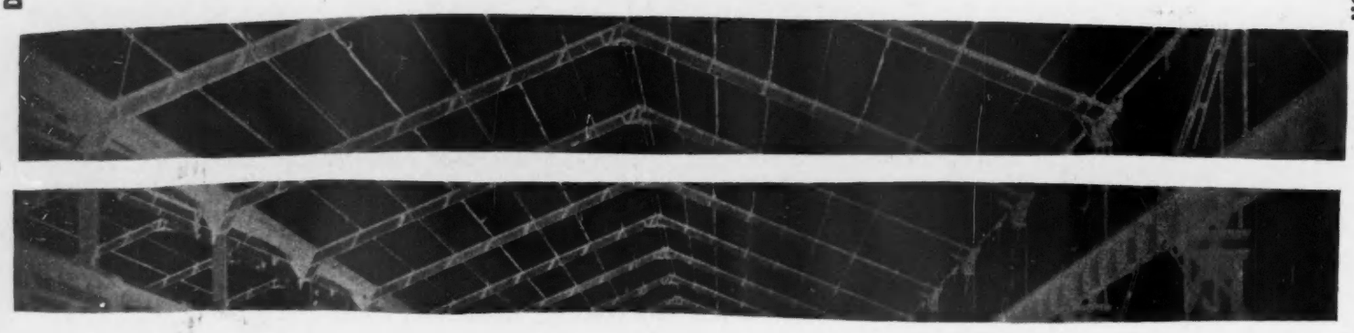
# The Portal Roof...



*. . modern construction for the modern factory . . . .*

Ever in the forefront of modern development, Lambhill show this example of a welded Portal Roof—a twin—span construction with spans measuring 70 ft. by 500 ft. giving maximum unobstructed headroom. There are no members below the rafter line to accumulate dust and dirt; the construction permits easy complete insulation. Maintenance costs are low.



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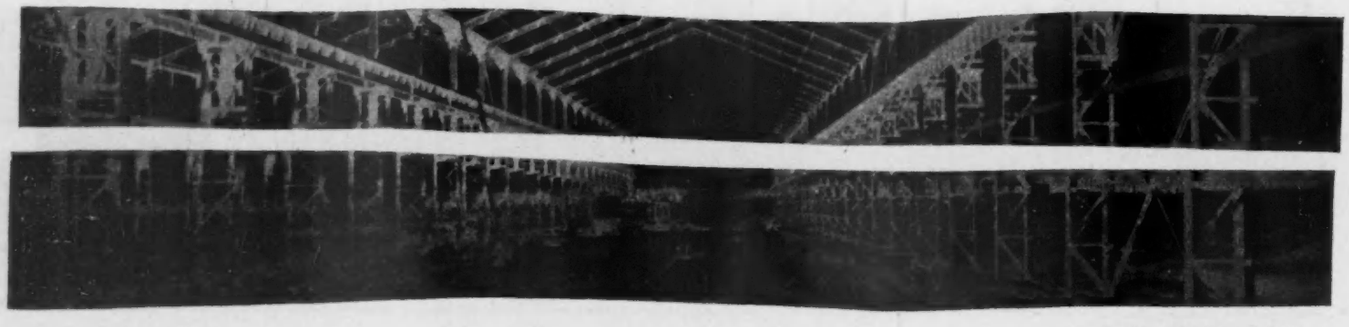
CONSTRUCTION



DESIGN · FABRICATION · ERECTION

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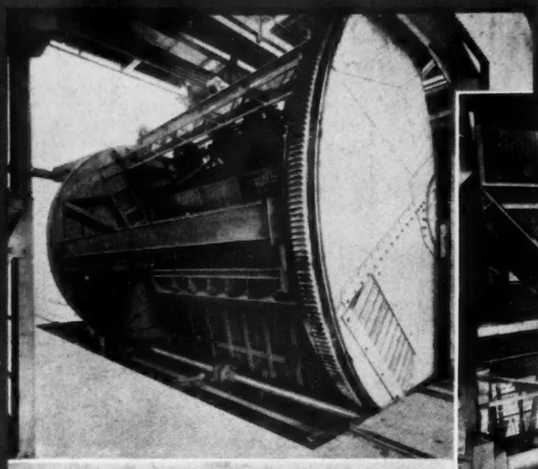
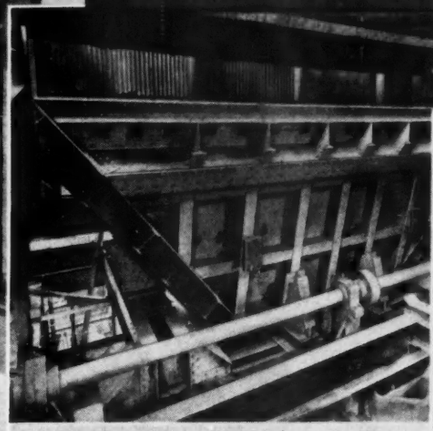
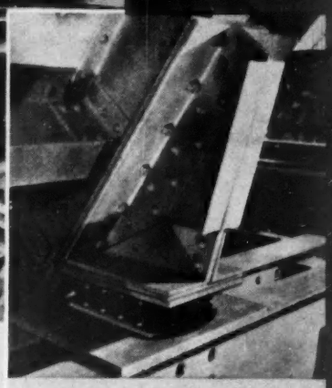


*. Ore is tipped out of the truck here . . .*



*falls into this hopper . . .*

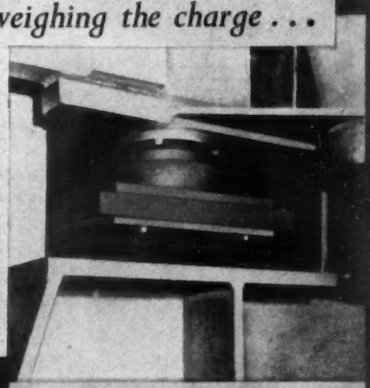


*mounted on 6 Metalastik mountings.*

# Softening the shock loads

At the Stanton Ironworks, ore is discharged from railway wagons by means of a tippler and crashes into a hopper. Normally 25-35 tons may be discharged in 30 seconds, sometimes in a steady stream but occasionally lumps of iron ore, exceeding 3½ tons fall 10-ft., resulting in impact loads which are considerable and could be damaging. Furthermore the vibration and shock impulses—unless checked—would be transmitted to adjacent buildings and plant. Accordingly the suppliers of the plant, Mitchell Engineering Ltd. called in Metalastik to reduce the harmful effects by providing mountings which normally support 11 tons each, deflecting 0.1". Under the extreme conditions already mentioned the deflection is 0.3", making a very considerable reduction in the shock effect. A similar problem arose at Samuel Fox's works in Sheffield where a magnet crane discharges large masses of scrap metal into a 60-ton scale transfer car from a considerable height. The loadcells employed had to be safeguarded from excessive shock loads in order to maintain their high accuracy indefinitely. Davy and United Instruments Limited, who engineered the loadcell weighing equipment into the installation, met the problem by incorporating Metalastik mountings as illustrated in the accompanying pictures. Whether for a small instrument, a diesel engine or a great piece of industrial plant, Metalastik mountings can always improve the conditions.

*On this transfer car for weighing the charge . . .*



*. . . the 'loadcell' is protected by Metalastik mountings.*

METALASTIK

METALASTIK LTD., LEICESTER

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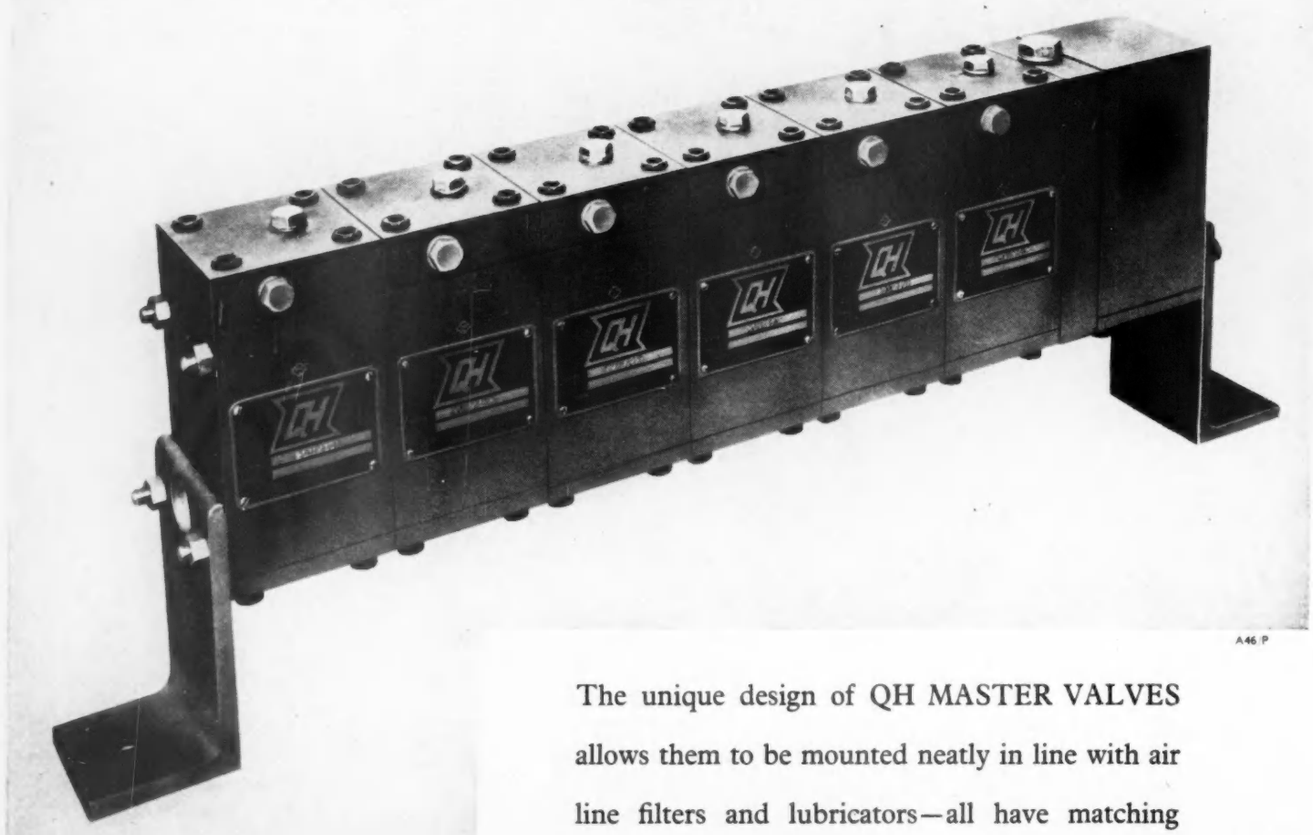
# with QH PNEUMATIC MASTER VALVES

(Patent applied for)

## your valve panels can be as neat as this



A46/P

The unique design of QH MASTER VALVES allows them to be mounted neatly in line with air line filters and lubricators—all have matching interconnecting pilot and main air ports.

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*setting new standards in Pneumatic Equipment*

*For further details write to:* QUALTER, HALL & CO. LTD., P.O. Box 8, Railway Foundry, Barnsley

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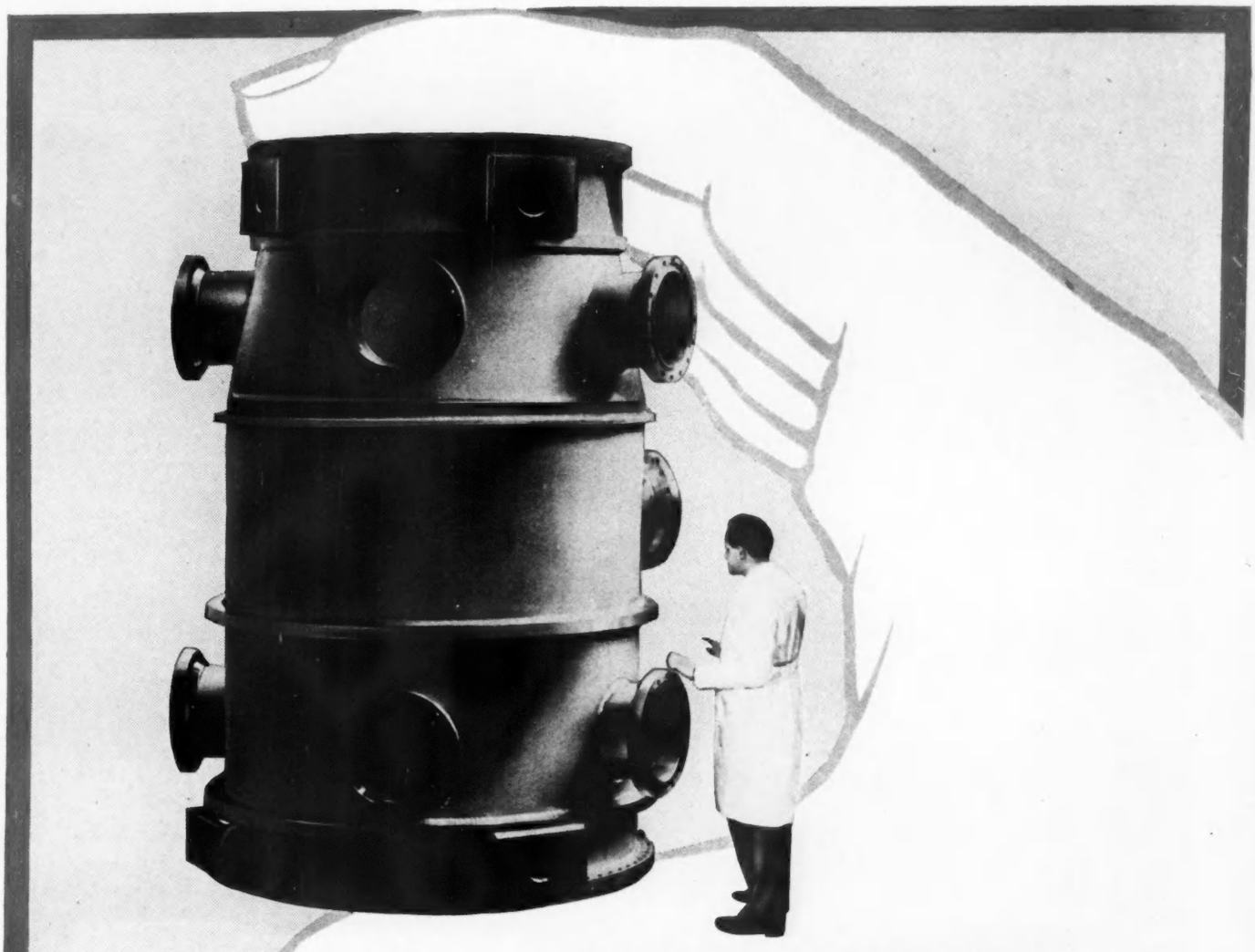

# what sort of scale?

Pressure vessel, generally from ¼" aluminium plate, with 2½" flanges. Weight 35 cwt. It is in fact about 9 ft. high.

The things we make at Fairey Engineering are not limited to any arbitrary scale of size, quantity or quality.
All the resources, capabilities and skills accumulated by the Fairey Group over 40 years have been further extended and are now being applied to the fabrication of vessels and structures of almost any size or complexity and in any material.
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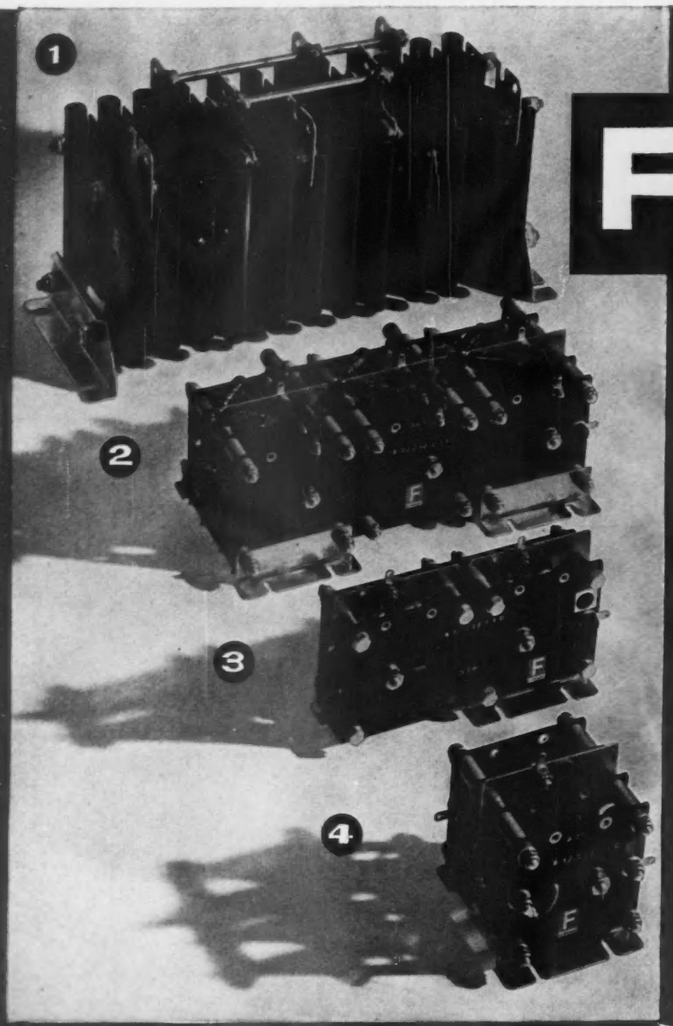


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1 3 phase type
Ratings up to 84/168 amps and 300/150 volts DC
Size 13½" x 6½" x 4½"

2 3 phase type
Ratings up to 22/44 amps and 300/150 volts DC
Size 8½" x 4½" x 3½"

3 1 phase type
Ratings up to 16 amps and 200 volts DC
Size 5" x 2" x 3¼"

4 1 phase type
Ratings up to 16 amps and 200 volts DC
Size 2¾" x 3½" x 3½"

## Special Features

- Reliability at high temperature.
- High power to space ratio.
- Very high rectification efficiency.

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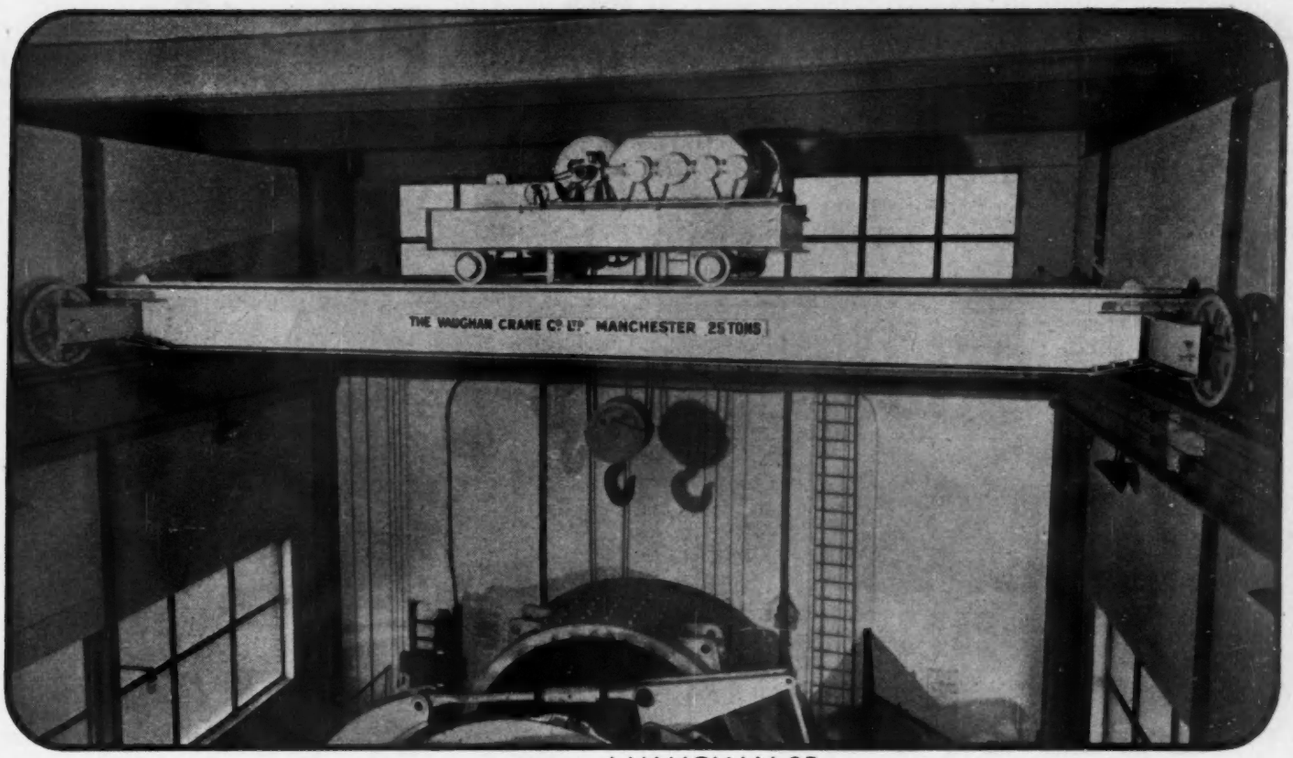


a typical VAUGHAN 25 ton crane (with acknowledgements to the National Coal Board)

# the CRANE for the JOB

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LIGHT DUTY
MEDIUM INDUSTRIAL
HEAVY INDUSTRIAL
STEELWORKS

(Capacity. Minimum 1 ton Maximum 200 tons)

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SEMI-GOLIATH
SPECIAL PURPOSE
WALL JIB

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Mr. Manufacturer please do not allow your employees to work in conditions where air pollution exists.

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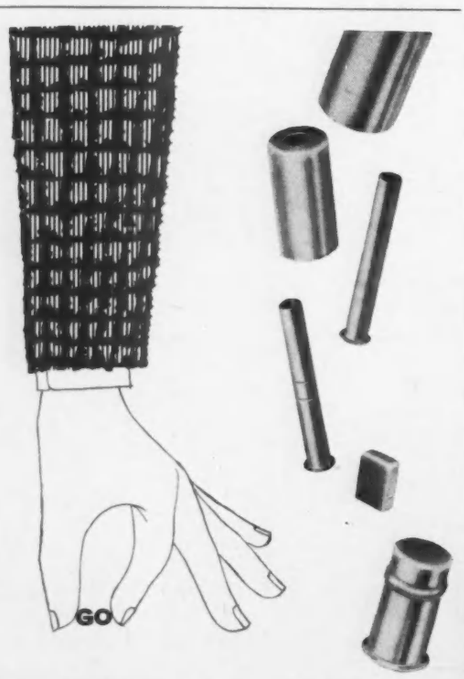
For over 50 years we have specialised in the production of Deep Drawn Metal Pressings in all metals and finishes.




*and we'll design and produce to your requirements.*

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PERCY ROAD, GREET, BIRMINGHAM, 11. *Telephone: SPRingfield 4491. (P.B.X.)*

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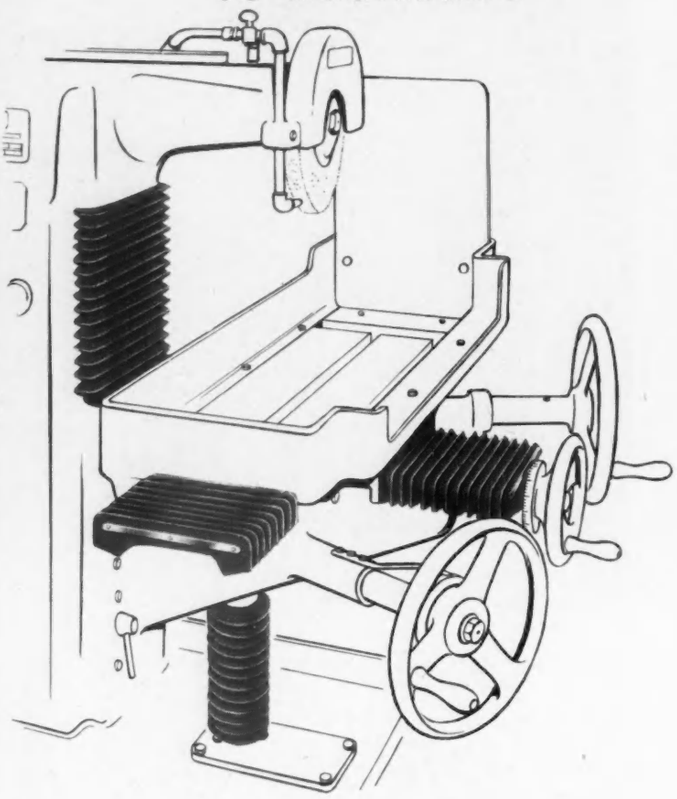
**Protection - made to measure**



Fortox Flexible Covers are designed and manufactured specifically to fit any part of a machine requiring protection. Single items can be supplied promptly, usually without tool charge. Made in neoprene-nylon, proofed leather or coated fabrics, according to conditions, Fortox Covers exclude dirt from sliding members, cutting down wear, reducing maintenance and lengthening the life of a machine. Write now for our technical book 'The Design and Use of Corrugated Covers'.

Ask also about Fortox Leather Seals and Packings made to requirements. A range of high accuracy polyester, silicone or synthetic rubber impregnated leathers is available to ensure positive sealing over a wide variety of conditions.

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Tel. Holborn 7295. Grams: Beakbane, Westcent, London.

*Beardmore*

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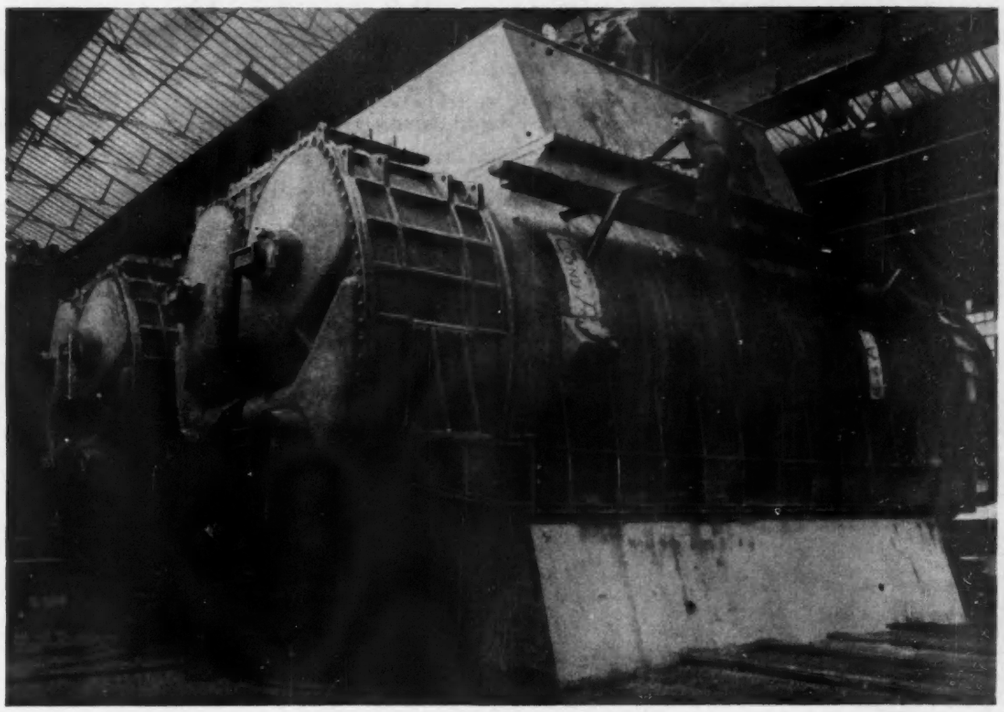
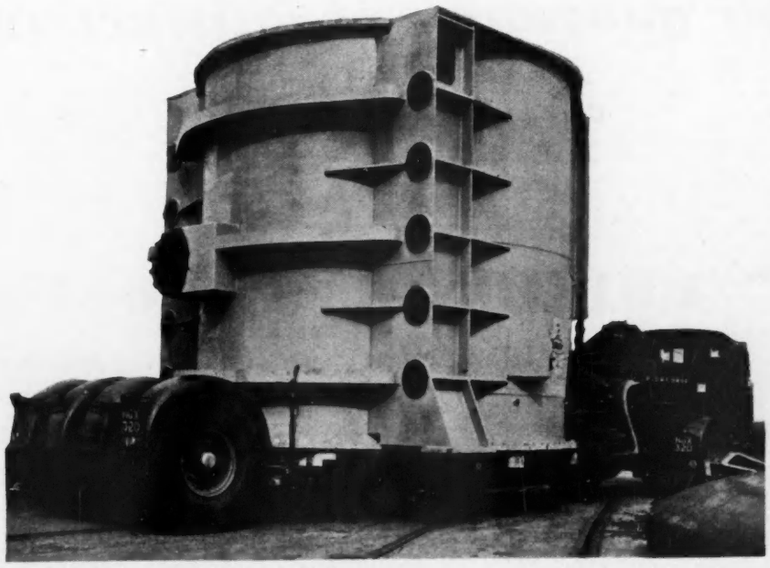


**Weir**

# REGENERATIVE CONDENSERS *for* SKELTON GRANGE "B"

*Merz & McLellan, Consulting Engineers*



*A half of one of the shells leaving the Works.*

This is the first of four Weir Regenerative Condensers for the 120 MW Turbo-alternators at the C.E.G.B. Skelton Grange "B" Power Station. Each shell is 25 ft. 9 in. long and 14 ft. in diameter, and the total cooling area is 85,000 sq. ft. (over 60 miles of tubing!).

***Highest Vacuum obtainable under given working conditions.***

***Condensate delivered at temperature corresponding to the vacuum — minimum temperature drop — highest thermal efficiency.***

***Condensate thoroughly de-aerated. Any air is efficiently cooled.***

*Also Manufactured under licence for marine service by the leading shipbuilders.*

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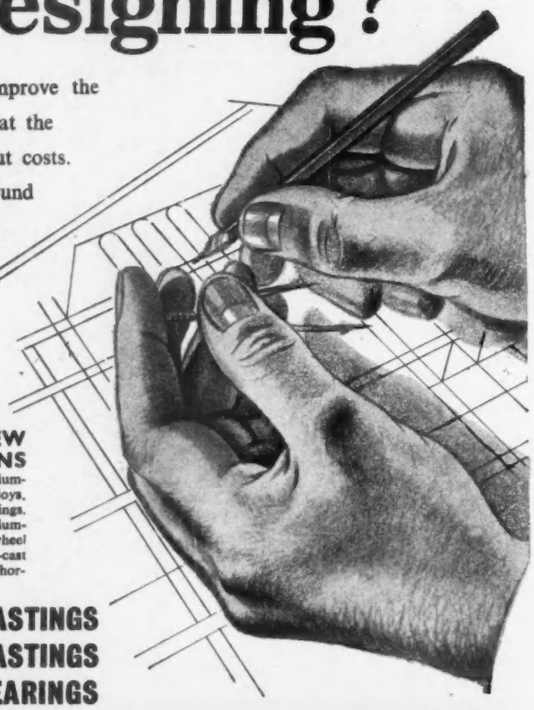
# ARE YOU re-designing?

Very often our design engineers can improve the structural form of your castings, and at the same time reduce complexity and cut costs. That way you'll get cheaper, more sound casting of unequalled quality and accuracy. This technical teamwork can tackle *all* your casting problems —and *solve* them.



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**CASTINGS FROM A FEW OUNCES TO 10 TONS**
in phosphor-bronze, gun-metal, aluminium-bronze, manganese-bronze, and light alloys. Precision machined bushes and bearings. Specialists in high-tensile aluminium-bronze castings, centrifugal-cast wheel blanks, shell moulded castings, and chill-cast rods and tubes. Continuous cast phosphor-bronze bars up to 12 feet lengths.

**NON-FERROUS CASTINGS**
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*Head Office: HANLEY, Phone: Stoke-on-Trent 22184/5/6/7. LONGPORT, Phone: Newcastle, Staffs 51433/4.*

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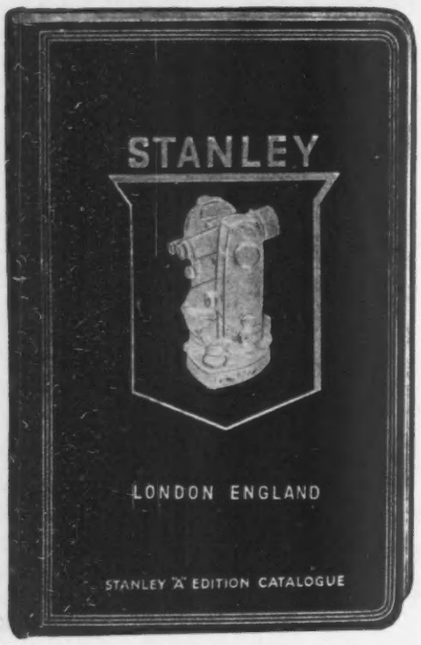


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## "A" EDITION CATALOGUE

*The 'Stanley' range comprises all that is best in:—*
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*Drawing Instruments*
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Copies of the "A" Catalogue will be sent on request.
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**W. F. STANLEY & CO., Limited**

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| *Showrooms :—* | *79/80 High Holborn, London, W.C.1.* | *(Holborn 2684)* |
| *Branches :—* | *13, Railway Approach, London Bridge, London, S.E.1.* | *(Hop 0871/2)* |
| | *52, Bothwell Street, Glasgow, C.2.* | *(Central 7130)* |

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# CLASSIFIED ADVERTISEMENTS

**PUBLIC APPOINTMENTS · SITUATIONS VACANT · TENDERS · EDUCATIONAL · BUSINESSES and PREMISES · BUSINESS OPPORTUNITIES PATENTS · MISCELLANEOUS · AGENCIES · DIRECTORS · PARTNERSHIPS**

**Lineage Rate.** 4/6 per line of approximately 6 words. **Minimum 18/-** **Inch Rate.** 54/- per single column inch and pro rata. 12 lines to 1 inch.

There are reduced rates (i.e., not on a pro rata basis) for advertisements of ¼-page (12 column inches) and upwards, e.g., ¼-page £29 10s. ½-page £54. Full page £100.

**FOR SALE · MACHINERY, etc., WANTED · AUCTION SALES · SITUATIONS WANTED · SUB-CONTRACTING · DESIGN SERVICES · FOR HIRE**

**Lineage Rate.** 4/- per line of approximately 6 words. **Minimum 16/-** **Inch Rate.** 48/- per single column inch and pro rata. 12 lines to 1 inch.

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**Run-On and Semi-Displayed Styles.** Both these styles are available for single column width advertisements of any depth up to 12 inches.

**Displayed and Illustrated Styles.** The minimum size for a Displayed advertisement is 3 inches single column, for an Illustrated advertisement it is a ¼-page (12 column inches). Thereafter the sizes for both progress in steps 3 inches deep across 1, 2, 3 or 4 columns.

**Use of Box Number.** 2/- which includes forwarding of replies.

**Copy Dates.** Tuesday for publication on Friday of the same week. If proofs are wanted, copy is required on Thursday for publication on Friday of the following week.

*Advertisements for publication should be addressed to :*—**Classified Advertisement Dept., "THE ENGINEER," 28 Essex Street, Strand, London, W.C.2**

*Urgent advertisements may be telephoned to CENtral 6565.*

## PUBLIC APPOINTMENTS

### COUNTY BOROUGH OF GRIMSBY EDUCATION COMMITTEE

#### COLLEGE OF FURTHER EDUCATION

Principal : E. S. GREEN, B.Sc., A.R.I.C.

#### LECTURER IN MECHANICAL ENGINEERING

Applications are invited for appointment as LECTURER IN MECHANICAL ENGINEERING (following the promotion of the present holder of the post).

Applicants should be Graduates in Engineering or hold equivalent industrial qualifications. Salary in accordance with the Burnham Technical Report 1959 (£1370 to £1550—with increments for approved industrial or teaching experience).

Further particulars of this appointment and application forms may be obtained from the undersigned, to whom they should be returned within fourteen days of the appearance of this advertisement.

R. E. RICHARDSON,
Director of Education.

Education Office,
Eleanor Street,
Grimsby.
18th January, 1960. E8648

### WELSH COLLEGE OF ADVANCED TECHNOLOGY, CATHAYS PARK, CARDIFF

#### READER IN MECHANICAL ENGINEERING

Applications are invited for the following posts :

READER IN MECHANICAL ENGINEERING. Salary £1800 by £50 to £2100. The candidate appointed will have as primary responsibility the initiation and supervision of research work.

SENIOR LECTURER IN MECHANICAL ENGINEERING. Salary £1550 by £50 to £1750. Applicants should be University graduates in Mechanical Engineering and have had adequate industrial experience.

Forms of application, together with further particulars, may be obtained from the Principal, and should be returned as soon as possible.

ROBERT E. PRESSWOOD,
Clerk to the Governors.

City Hall,
Cardiff.
January, 1960. E8666

### UNIVERSITY OF LIVERPOOL

#### LECTURERS

Applications are invited for the following posts in the Department of Mechanical Engineering :

(a) LECTURER.—The initial salary will be within the range £900–£1500 per annum, according to age, qualifications and experience.

(b) TEMPORARY SENIOR LECTURER OR LECTURER.—The appointment will be for a period of twelve months from 1st October, 1960. The salary will be within the range £900–£1700, according to age, qualifications and experience.

Applications, stating age, academic qualifications and experience, together with the names of three referees, Ref. CV/E, should be received not later than 22nd February, 1960, by the Registrar, from whom further particulars of the conditions of appointment may be obtained. E8638

### UNIVERSITY OF NOTTINGHAM

#### I.C.I. RESEARCH FELLOWSHIPS

Applications are invited for Imperial Chemical Industries Research Fellowships in Chemistry (including Agricultural Chemistry), Physics, Pharmacy, Engineering, Metallurgy and related subjects, tenable at the University of Nottingham. A number of appointments may be made as from 1st October, 1960, with a normal tenure of three years. The salary will be within the scale £700–£1000 per annum depending on qualifications and experience. Fellows will have status as members of the academic staff and will be eligible for F.S.S.U. benefits and children's allowances.

Further particulars and forms of application may be obtained from the Registrar, to whom applications must be returned not later than 31st March, 1960. E8658

## PUBLIC APPOINTMENTS

### BOROUGH POLYTECHNIC, BOROUGH ROAD, S.E.1

Principal : JAMES E. GARSIDE, M.Sc. Tech. Ph.D., F.R.I.C., F.I.M., F.Inst.F.

#### DEPARTMENT OF MECHANICAL ENGINEERING

Head of Department : G. L. H. BIRD, B.Sc. (Eng.), M.I.Mech.E., M.Inst.R.

#### LECTURERS IN MECHANICAL ENGINEERING

The Governors invite applications for the following appointments :

TWO LECTURERS IN MECHANICAL ENGINEERING

Post 1.—Candidates should have specialised knowledge and experience to teach advanced production engineering with special reference to deformation processes.

Post 2.—Candidates should have specialised knowledge and experience in Heat Transfer theory and Engineering Thermodynamics and their applications.

For both appointments, candidates should be University Graduates in Mechanical Engineering and have had responsible industrial and/or research experience. For Post 1, post-Graduate qualifications in some aspect of Production Engineering would be an added qualification. For both appointments there are excellent opportunities for research.

ASSISTANT LECTURER (GRADE B) IN MECHANICAL ENGINEERING

Candidates should be University Graduates in Mechanical Engineering and have had appropriate industrial experience. Duties include teaching Engineering Science and Engineering Drawing and Design to National Certificate standard and above. Opportunities will be given for participation in teaching in advanced "Sandwich" courses and in research.

Whilst it is desired to fill the above posts by 1st May, 1960, applications will be entertained from candidates unable to take up an appointment before 1st September, 1960.

Further particulars and application form, which should be returned as soon as possible, obtainable from the undersigned.

FREDK. J. PACKER,
E8696 Clerk to the Governing Body.

### UNIVERSITY OF LIVERPOOL

#### LEVERHULME POSTGRADUATE FELLOWSHIPS

Applications are invited for Three LEVERHULME POSTGRADUATE FELLOWSHIPS, Two in the Faculty of Science and One in the Faculty of Engineering, tenable for one year at the value of £600, and renewable for a second year.

Applications, three copies, stating age, details of qualifications and experience, publications, research work in progress and completed, and an outline of the proposed field of research, together with the names of two referees, quoting Ref. CV/E, should be received not later than 1st March, 1960, by the Registrar, from whom further particulars may be obtained. E8639

### NOTTINGHAM AND DISTRICT TECHNICAL COLLEGE, BURTON STREET, NOTTINGHAM

Principal : D. A. R. CLARK, M.Sc. (Tech.), M.I.Mech.E.

#### RESEARCH ASSOCIATESHIP

Applications are invited for the following full-time RESEARCH ASSOCIATESHIP, Mechanical Engineering Department. This research post offers considerable scope. Applicants should possess an Engineering Degree of a British University and the person appointed will be encouraged to prepare for a higher Degree if appropriate.

The salary for the above post is as follows : £630 by £50 to £750 per annum.

Further particulars and form of application may be obtained from the Principal, to whom completed forms should be returned not later than 20th February, 1960. E8690

## PUBLIC APPOINTMENTS

### UNIVERSITY OF SYDNEY

#### DEPARTMENT OF CIVIL ENGINEERING

#### APPOINTMENTS

Applications are invited for the following positions in the Department of Civil Engineering.

(1) SENIOR LECTURESHIP IN CIVIL ENGINEERING

Candidates should have had research and teaching experience in Strength of Materials.

(2) LECTURESHIP/SENIOR LECTURESHIP IN CIVIL ENGINEERING.

The successful applicant will be required to teach and engage in research in Hydraulics.

The salary for a Senior Lecturer is within the range £A2200–£A80–A2600 per annum : for a Lecturer, within the range £A1500–£A90–£A2100 per annum. In each case cost-of-living adjustments will be allowed (at present £A23 per annum). The salary is subject to deductions under the State Superannuation Act. The commencing salary will be fixed according to the qualifications and experience of the successful applicant.

Under the Staff Members' Housing Scheme, in cases approved by the University and its Bankers, married men may be assisted by loans to purchase a house.

Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36, Gordon Square, London, W.C.1.

Applications close, in Australia and London, on 12th March, 1960. E8682

### UNIVERSITY COLLEGE OF THE WEST INDIES

#### CHAIR OF CIVIL OR MECHANICAL ENGINEERING

Applications are invited for the CHAIR OF CIVIL OR MECHANICAL ENGINEERING. Applicants should possess broad interests within the whole field of Engineering Education and be interested in the detailed design and equipment of laboratories for a new Faculty. Salary £2500 per annum. Child allowance, F.S.S.U. Unfurnished accommodation 5 per cent basic salary. Passages for up to 5 persons on appointment, normal termination and study leave (once every three years).

Detailed applications (6 copies), naming 3 referees, by 28th February, 1960, to Secretary, Inter-University Council for Higher Education Overseas, 29, Woburn Square, London, W.C.1, from whom further particulars may be obtained. E8686

### UNIVERSITY OF SOUTHAMPTON

#### I.C.I. RESEARCH FELLOWSHIPS

Applications are invited for I.C.I. Research Fellowships in Biochemistry, Chemistry, Engineering and Physics, to which some appointments may be made during the current academic year. The appointments will date from 1 October, 1960, or earlier if a selected candidate is available before that date. Salary according to qualifications and experience within range £700–£1000 per annum. F.S.S.U. and Children's Allowances. Applications (15 copies) containing list of publications and names of two referees should be sent not later than 5 March, 1960, to the Secretary and Registrar, from whom further particulars may be obtained. E8655

### LONDON COUNTY COUNCIL

#### ROBERT BLAIR FELLOWSHIP IN APPLIED SCIENCE AND TECHNOLOGY

Applications are invited for the award of the Robert Blair Fellowship tenable for one year of advanced study or research abroad in applied science and technology. The value of the award is subject to variation, and, if the country selected should be Canada or the U.S.A., may be up to £2,000 (subject to income tax).

Candidates must be British subjects and at least 21 years of age.

Further particulars and forms of application may be obtained from the Education Officer (ED/WA/14), The County Hall, S.E.1 (stamped, addressed foolscap envelope necessary) for return by 12 March, 1960. (79). E8580

## PUBLIC APPOINTMENTS

### CITY OF OXFORD EDUCATION COMMITTEE

#### COLLEGE OF TECHNOLOGY

#### APPOINTMENTS

Applications are invited for the following posts from Easter, 1960 :

LECTURER IN ELECTRICAL ENGINEERING for O.N.C. and H.N.C. Courses, preferably with ability also to assist with work for Part III I.E.E. Good Degree or Corporate Membership (by examination) of I.E.E., and industrial and some teaching experience required.

ASSISTANT GRADE "B" in Physics for G.C.E. "O" and "A" levels and as a main and ancillary subject for National Certificates. Graduate required.

Salaries in accordance with the Burnham Technical Report, 1959.

Further information can be obtained from the Principal, College of Technology, Headington Road, Oxford, to whom applications must be returned within 14 days of the appearance of this advertisement. E8713

### UNIVERSITY OF LONDON KING'S COLLEGE

#### LECTURER IN MECHANICAL ENGINEERING

Applications are invited for this post. Candidates should have a good Honours degree and some experience of teaching and/or research in Engineering Science. Industrial or other professional experience is also desirable.

The salary will be on the scale £900 by £50 p.a. to £1350 by £75 p.a. to £1650, with starting point according to qualifications and experience. A London allowance of £60, family allowances, and F.S.S.U. benefits will also be payable.

The formal conditions of appointment and application forms may be obtained from the Registrar, King's College, London, Strand, W.C.2. Completed forms must reach him by February 29th. E8707

### LONDON COUNTY COUNCIL

#### WANDSWORTH TECHNICAL COLLEGE

#### LECTURER

London County Council Wandsworth Technical College require LECTURER in Mechanical Engineering Department to teach Strength of Materials and Theory of Structures up to H.N.C. standard. Graduate or equivalent qualifications, industrial and teaching experience desirable. Burnham F.E. Scale (Men) £1370 by £35 to £1550, plus London Allowance. Increments within the scale for approved experience.—Application forms from Secretary, at College, Wandsworth High Street, S.W.18, returnable by 10 February. (82) E8670

### BRADFORD INSTITUTE OF TECHNOLOGY

Principal : E. G. EDWARDS, Ph.D., B.Sc., F.R.I.C.

Applications are invited for the posts of

**SENIOR LECTURER IN MECHANICAL ENGINEERING**
**LECTURER IN MECHANICAL ENGINEERING**

Candidates should be well-qualified and industrial and research experience would be a recommendation. The successful candidates will be required to teach one or more subjects to honours degree standard. They will be encouraged to undertake research and adequate facilities will be available.

Salary scales : Senior Lecturer, £1550–£1750 per annum. Lecturer, £1370–£1550 per annum.

Previous industrial and research experience at a suitable level may be taken into account in fixing the commencing salary.

Further particulars and forms of application may be obtained from the Registrar, Bradford Institute of Technology, Bradford, 7.

HENRY PATTEN,
E8712 Clerk to the Governors.

**Classified Advts. continued on page 106**

## PUBLIC APPOINTMENTS

### LANCHESTER COLLEGE OF TECHNOLOGY, COVENTRY

Principal : A. J. RICHMOND, B.Sc. (Eng.), (Lond.), Ph.D., M.I.Mech.E.

#### LECTURERS

Applications are invited for the following posts to complete the initial staffing of this new College which will commence to function from the Summer of 1960. The College will offer advanced Sandwich and full-time courses, H.N.C. and certain more advanced City and Guilds Courses, as well as a range of professional courses in Commerce and Management Studies.

For all posts duties to commence from dates to be arranged but not later than 1st September, 1960.

DEPARTMENT OF MECHANICAL ENGINEERING : One Principal Lecturer who will rank as Deputy Head of Department. One Senior Lecturer able to teach Mechanics of Fluids and Theory of Machines ; subsidiary Theory of Structures an advantage. Candidates should be University graduates and chartered Mechanical Engineers.

DEPARTMENT OF PRODUCTION ENGINEERING : Three Lecturers able to teach one or more of the following : Metrology and Inspection, Machine Tool Design and Application, Production Tooling and Design. Candidates should be corporate members of the Institution of Production Engineers and preferably at least graduate members of the Institution of Mechanical Engineers.

DEPARTMENT OF AERONAUTICAL ENGINEERING : One Lecturer able to teach Aero, Design and Structures. Candidates should be University graduates and Associate Fellows of the R.Ae.S. (or be qualified to join the Society).

DEPARTMENT OF ELECTRICAL ENGINEERING : Three Senior Lecturers : one specialising in Electrical Power (including generation), Distribution and Utilisation ; one specialising in Control Systems and related subjects ; one specialising in Digital Circuit and Pulse Techniques. Candidates should be University graduates and chartered electrical engineers.

Appropriate Industrial or Commercial or Research experience essential for all posts.

Salaries (Men) : Principal Lecturer, £1750 by £50 to £1900 p.a. Senior Lecturers, £1550 by £50 to £1750 p.a. Lecturers, £1370 by £35 (4) and £40 (1) to £1550 p.a.

In certain circumstances candidates may be paid a commencing salary above the minimum of the respective scales.

Women receive slightly less at present but equal pay will apply from April, 1961.

Further particulars and application forms (stating the posts or posts concerned) from the Registrar, Lanchester College of Technology, temporary address—Butts, Coventry, to whom completed forms should be returned by 25th February, 1960.

W. L. CHINN,
Director of Education.

E8706

### ROYAL NAVAL SCIENTIFIC SERVICE

#### SENIOR SCIENTIFIC OFFICERS AND SCIENTIFIC OFFICERS

SENIOR SCIENTIFIC OFFICERS and SCIENTIFIC OFFICERS required in following localities : LONDON AREA : MECHANICAL ENGINEER with sound knowledge of basic principles of thermo and fluid dynamics, to carry out research programme in particular field of applied hydrodynamics. Experience in modern methods of design and research on axial flow compressors, turbines or pumps an advantage. MECHANICAL ENGINEER for research on precision gear design. MECHANICAL ENGINEER for work on propulsion problems. APPLIED MATHEMATICIAN for research of basic nature on stability of underwater vehicles ; knowledge of theoretical hydrodynamics and theory of control mechanisms an advantage. APPLIED MATHEMATICIAN or THEORETICAL PHYSICIST for acoustic analysis. APPLIED MATHEMATICIAN for work with electronic computers, with special reference to research into general underwater physical problems. ELECTRONIC PHYSICISTS for data handling and analysis problems. EXPERIMENTAL PHYSICIST for research in underwater acoustics. PHYSICIST interested in operation performance. CLASSICAL PHYSICISTS.

BALDOCK : PHYSICISTS or APPLIED MATHEMATICIANS for research in Metal or Quantum Physics.

PORTSMOUTH : PHYSICISTS with experience in field of microwave techniques. ELECTRONIC/ELECTRO-MECHANICAL ENGINEERS (experience in servo-mechanisms an advantage).

HASLEMERE : ELECTRONIC ENGINEER.

PORTLAND : PHYSICISTS or APPLIED MATHEMATICIANS for research in underwater acoustics. PHYSICISTS (general). ELECTRICAL ENGINEERS with advanced electronic design experience. MECHANICAL ENGINEERS. PHYSICAL CHEMISTS.

POOLE : CHEMICAL ENGINEERS. CHEMISTS with experience in rubber technology.

ROSYTH : MECHANICAL ENGINEER with experience in welding development. ELECTRONIC PHYSICISTS.

Candidates must normally be natural born British subjects of natural born British parents, with First or Second-Class Hons. Degrees or equivalent qualifications. S.S.O.s must have had three years' post-graduate experience and be not less than 26 years of age. Salaries (men) : S.S.O., £1233–£1460 ; S.O., £655–£1150 (London), somewhat lower in provinces.

Appointments unestablished (with F.S.S.U. benefits), but opportunities may occur for those under 32 to compete for established posts.

Forms from M.L.N.S., Technical and Scientific Register (K), 26, King Street, London, S.W.1 (quote A.483/9A). E7844

## PUBLIC APPOINTMENTS

### RUGBY RURAL DISTRICT COUNCIL

#### WIBTOFT WATER SUPPLY CONTRACT NO. 12
#### WOLSTON AREA SEWERAGE AND SEWAGE PURIFICATION CONTRACT NO. 13

#### APPOINTMENT OF CLERK OF WORKS OR 2ND ASSISTANT RESIDENT ENGINEER

Applications are invited for appointment in either of the above capacities, to assist the Resident Engineer in the supervision of the following works :

The laying of 5½ miles of 6 inch and 9 inch concrete and salt-glazed ware sewers, the re-drainage of some 600 houses and the construction of three pumping stations and of sewage purification works for 5000 people.

Work on the Contract is already in progress, under the direction of the Consulting Engineers, Messrs. J. D. and D. M. Watson, MM.I.C.E., 67, Tufton Street, Westminster, London, S.W.1.

The salary for appointment in either capacity is £800 per annum and, subject to satisfactory service, the appointment will be for approximately 12 months and will be terminable by one month's notice on either side.

A car mileage allowance will be paid and the Council will be prepared to consider making housing accommodation available, if required.

Applicants, who must have had experience of similar work, should apply in writing to the undersigned not later than 6th February, 1960, giving full particulars of age, qualifications and experience, and the names and addresses of two persons to whom reference may be made.

Canvassing will disqualify.

H. A. WILDE,
Clerk of the Council.

Council Offices,
24, Warwick Street,
Rugby.
19th January, 1960. E8649

### BRITISH RAILWAYS

#### LONDON MIDLAND REGION

#### STRUCTURAL ENGINEERS AND ENGINEERING ASSISTANTS

British Railways, London Midland Region, have employment at Euston for STRUCTURAL ENGINEERS (Reference 91).

Should be capable of the design and detailing of railway structures in steel, reinforced and prestressed concrete. Membership of the Institution of Civil Engineers or the Institution of Structural Engineers, desirable.

ENGINEERING ASSISTANTS (Reference 92).

Should have experience in rail track layouts and general civil engineering work. Should be capable of preparing schemes on own initiative.

Salary range : £833 to £985 per annum. Superannuation scheme, five-day week, residential and other travelling facilities.

Applications, quoting reference and giving details of age, experience and educational background, to :

Chief Civil Engineer,
British Railways, London Midland Region,
5a, Euston Grove,
London, N.W.1. E8637

### CITY OF SHEFFIELD

#### CITY ENGINEER AND SURVEYOR'S DEPARTMENT

#### CHIEF HIGHWAYS ASSISTANT, GRADE B

Appointment of CHIEF HIGHWAYS ASSISTANT, Grade B (£1315–£1530 per annum).

Applications are invited from suitably qualified and well-experienced Civil Engineers for the above appointment on the permanent staff of the City Engineer and Surveyor and Town Planning Officer (H. Foster, M.A., M.I.C.E., M.I.Mun.E.).

Applicants must be Chartered Civil and/or Municipal Engineers with considerable experience in the design and construction of roads in congested urban areas. The duties will include control and supervision of the staff of the highways design section and staff management experience is therefore essential.

Superannuable post, N.J.C. conditions of service, medical examination.

Applications, stating age, education and training, experience, qualifications, present and past appointments (with dates and salaries), and quoting the names of two referees, to be submitted to the undersigned by the 8th of February, 1960.

JOHN HEYS,
Town Clerk.

E8620

### CITY OF NOTTINGHAM WATER DEPARTMENT

#### APPOINTMENT OF CIVIL ENGINEERING ASSISTANT

Applications for the above permanent, pensionable appointment are invited from Graduate Members of the Institution of Civil Engineers or from University Graduates who have had five years' engineering experience (including the period spent on theoretical training). Salary, dependent upon qualifications and experience, in the special grade for Engineering Assistants (£785 by £40 (6) by £45 to £1070).

Applications, with names of two persons to whom reference may be made, to Engineer and General Manager, Water Department, Castle Boulevard, Nottingham, not later than the 12th February, 1960.

T. J. OWEN,
Town Clerk.

E8691

## PUBLIC APPOINTMENTS

### CITY OF BRADFORD

#### ENGINEERING ASSISTANTS

Applications are invited for the following superannuable appointments in the City Engineer and Surveyor's Department, on the grades indicated :

(a) SENIOR ENGINEERING ASSISTANT, Post 13, Special Grade (£785–£1070).

(b) ENGINEERING ASSISTANT, Post 35, Post 120, Grade A.P.T. 1 or Special (£610–£765 or £785–£1070).

(c) JUNIOR ENGINEERING ASSISTANTS, Posts 52 and 63, Grade A.P.T. I (£610–£765).

Applicants for Post (a) should preferably hold an Engineering Degree, be A.M.I.C.E./A.M.I.Mun.E., and have had a good general civil engineering training.

Applicants for (b) should have completed their professional training. Salary on Special Grade will be payable to the successful candidate holding an Engineering Degree or be A.M.I.C.E./A.M.I.Mun.E.

Applicants for (c) should have completed their professional training and have had experience in Municipal and/or Civil Engineering.

No housing accommodation can be provided.

Application forms obtainable from the City Engineer and Surveyor, Town Hall, Bradford, 1, with three testimonials, must be received by the undersigned by 21st February, 1960.

HENRY PATTEN,
Town Clerk.

Town Hall,
Bradford, 1. E8673

### GREAT YARMOUTH WATERWORKS COMPANY

#### APPOINTMENT OF CIVIL ENGINEERING STAFF

Applications are invited for the following appointments :—

(a) DEPUTY ENGINEER at a salary of £1310, rising, subject to satisfactory service, by annual increments of £60, £50, £50, £50 to a maximum of £1520 per annum.

The person appointed to this position would be required to occupy a house provided by the Company, rent and rates free, and valued for superannuation purposes at £80 per annum. A car allowance of £180 per annum would also be paid.

(b) SENIOR ENGINEERING ASSISTANT, at a salary of £1220–£1375 (A.P.T. V).

The Company will assist the successful candidate for post (b) to obtain housing accommodation if required.

Both posts are permanent and pensionable, subject to satisfactory medical examination.

Candidates for the post of Deputy Engineer must be qualified Civil Engineers with considerable experience in the design and operation of works of water supply.

Candidates for (b) must be qualified Civil Engineers, preferably with some experience of water supply and capable of undertaking the design and supervision of new works construction.

A considerable and varied programme of capital works extensions, &c., is planned or in progress.

Applications, giving full details of qualifications and experience, age, present and past employers and accompanied by not less than two testimonials, one of which must be from the present employer, to reach the undersigned, from whom any further information may be obtained, as soon as possible but in any case not later than the 6th February, 1960.

S. A. S. WALTON, O.B.E., A.M.I.C.E., M.I.W.E.,
Engineer.

84, York Road,
Great Yarmouth. E8630

## TENDERS

### KENT RIVER BOARD

#### LITTLE STOUR PUMPING STATION

TENDERS are invited for the SUPPLY and ERECTION of FOUR ELECTRICALLY DRIVEN VERTICAL SPINDLE AXIAL FLOW PUMPS, each of 50 cusecs capacity, required for the above pumping station, which is to be constructed near Stourmouth, Kent, approximately seven miles north-east of Canterbury.

Firms wishing to Tender should apply in writing for the specification and drawing to the Engineer to the Board, 78, College Road, Maidstone.

A. G. STIRK,
Clerk of the Board.

15th January, 1960. E8651

### MACCLESFIELD CORPORATION

#### LAMALOAD RESERVOIR

The Corporation will shortly be inviting TENDERS from a selected list of contractors for the CONSTRUCTION of an IMPOUNDING RESERVOIR of 420 m.g. capacity at Lamaload near Macclesfield, Cheshire. The contract involves the construction of a concrete buttress dam 600ft. long and 120ft. high and ancillary works.

Contractors experienced in this work are invited to submit their names to the undersigned by Monday, 15th February, 1960, and should give a list and particulars of similar works they have carried out since 1945.

A list of selected contractors to be invited will be prepared, in conjunction with the Corporation's Consulting Engineers, Messrs. Herbert Lapworth Partners, and it is intended that work should be commenced in the late spring or early summer of this year.

WALTER ISAAC,
Town Clerk.

Town Hall,
Macclesfield. E8677

## TENDERS

### DUNMOW RURAL DISTRICT COUNCIL

#### CONTRACT NO. 17

#### LITTLE HALLINGBURY SEWERAGE AND SEWAGE DISPOSAL

TENDERS are invited on a fixed price basis in accordance with the Ministry of Housing and Local Government Circular No. 31/57 for the CONSTRUCTION of SEWERAGE AND SEWAGE DISPOSAL WORKS at Little Hallingbury.

The sewerage comprises in all the laying of about 2260 linear yards of 6in. diameter S.G.W. sewer.

Extensions are to be made to the existing sewage disposal works and comprise a pyramidal sedimentation tank, biological filter, concrete sludge digestion tank, concrete sludge drying beds, extension to existing sand filter and humus tank and alteration to ancillary pipework, site roads and fencing.

General Conditions of Contract, Specification, Bills of Quantities and Drawings may be obtained from the Council's Consulting Engineers, Messrs. J. D. & D. M. Watson, MM.I.C.E., 67, Tufton Street, Westminster, S.W.1, on and after, 25th January, 1960, on payment of a deposit of ten guineas, refundable only to Contractors who submit bona fide tenders and return all documents and drawings. Deposit cheques should be made payable to Dunmow Rural District Council.

The Council do not bind themselves to accept the lowest or any tender.

Tenders must be returned in envelopes which do not bear any name or mark indicating the tender endorsed "Tender for Sewerage Contract No. 17," and delivered at the office of the undersigned by noon on 4th March, 1960.

A. H. BURTON,
Clerk of the Council.

Council Offices,
Dunmow, Essex. E8600

## EDUCATIONAL

### CHESHIRE EDUCATION COMMITTEE

#### CHESHIRE COUNTY TRAINING COLLEGE, ALSAGER

#### ONE-YEAR COURSE OF TEACHER TRAINING FOR CRAFTSMEN

At the request of the Ministry of Education, the Cheshire Local Education Authority will provide, at the above-named College, from September, 1960, a new ONE-YEAR COURSE designed to give skilled Craftsmen Teacher Training to enable them to take up posts as Teachers of Handicrafts in Secondary Schools.

Applications are therefore invited for admission to this Course from men who already possess appropriate qualifications, such as a Full Technological Certificate of the City and Guilds of London Institute, or a Higher National Certificate or Higher National Diploma, and who wish to be trained as teachers.

The particular academic requirements of individual students and the application of their craft skills to the needs of schools will be specially studied. The year of training will include periods of teaching in schools.

The basic salary scale for qualified assistant teachers is £520 per annum, rising by annual increments of £27 10s. and one final increment of £40, to a maximum of £1000. Additional increments are given for approved qualifications and training. Account may also be taken of approved industrial experience acquired over the age of 21, up to a maximum of twelve increments.

Anyone needing further advice about the Course, the qualifications required, the grants available to students while attending the Course, and the teaching prospects available at the end of the Course, should communicate with the Principal, the Cheshire County Training College, Alsager, Stoke-on-Trent. Applications for admission to the course should also be made to the Principal. Early application is advised.

JOHN G. KELLETT,
Director of Education.

County Hall,
Chester. E8689 E

### UNIVERSITY OF LONDON

A COURSE OF THREE LECTURES entitled "Some Basic Engineering Problems in Tidal Estuaries" : (i) "Tide-dynamics in Estuaries" ; (ii) "Diffusion and Energy Dissipation in Estuaries" ; (iii) "Sediment Problems in Estuaries," will be delivered by Professor A. T. Ippen (Massachusetts Institute of Technology), at 5.30 p.m., on 8th, 10th and 12th February, at the University of London, Senate House, W.C.1.

Admission Free, Without Ticket.

JAMES HENDERSON,
Academic Registrar.

E8640 E

### COVENTRY TECHNICAL COLLEGE

#### COURSE ON "METALLURGICAL FAILURES IN MECHANICAL PARTS"

A short COURSE intended for METALLURGISTS and ENGINEERS will be held on Thursday and Friday, 18th and 19th February, 1960. Course fee : 1 Guinea.

Particulars and application forms from Head of Chemistry Department. E8490 E

**A.M.I.MECH.E., B.Sc.,** City and Guilds, etc. Guarantee Postal Courses for all Exams. and Technical Divisions from Elementary to Degree standard including Automation Techniques. Approximately 95 per cent successes. 148-page prospectus free, on request.—B.I.E.T. (Dept. 22), 29, Wright's Lane, London, W.8. E114 E

## SITUATIONS VACANT

APPLICANTS ARE ADVISED TO SEND COPIES NOT ORIGINALS OF THEIR TESTIMONIALS UNLESS OTHERWISE REQUESTED.

**A DIVISIONAL MANAGER** is required by The British Refrasil Company Limited, Stillington, County Durham, to take charge of its Rostenit Division. Rostenit is a patented process for lining mild steel, concrete and other types of container with Stainless Steel, of particular interest to the brewing, distilling, chemical and similar industries. The British Refrasil Company is the sole U.K. Licensee. The Divisional Manager will be responsible for building up the Division's activities (in collaboration with Sales), recruiting and training the necessary labour force, the control of estimating and quoting and the execution of all contracts on site and in the works. Applications are invited from Engineers about 35 years old with A.M.I.Mech.E. or equivalent, knowledge of container fabrication and successful management experience in works and on site. Suitable applicants might now be employed as Engineering Executives in chemical or brewery plants. This post carries good pension and life assurance benefits, substantial starting salary and good prospects of advancement in a developing group of Companies.—Applications to be addressed to the Managing Director, The British Refrasil Company Ltd., Stillington, Co. Durham. E8693 A

**APPLICATIONS ARE INVITED** from ambitious and resourceful men to fill the position of TECHNICAL ASSISTANT to the Sales Manager of Electric Lamp Machinery Manufacturers near London. A permanent, progressive and interesting job is offered to the right person, who must possess a sound engineering and commercial background in the trade.—Applications, with full particulars of education, experience and salary required, to BOX No. E171, "The Engineer." A

**BP** requires PETROLEUM ENGINEERS for overseas service in its Exploration Department. Applicants, aged between 21–27, must possess an Honours Degree in Physics, Mechanical Engineering or Petroleum Engineering. Previous oilfield experience would be an advantage. Salary according to age, qualifications and experience. National Service obligations must have been fulfilled.—Write, stating age and full details of qualifications and experience, quoting F.579, to Box 3233, c/o 191, Gresham House, E.C.2. E8646 A

**BALL BEARING FACTORY** in the North of England require the services of a man thoroughly conversant with the manufacture of high carbon steel balls to first grade precision limits.—Please reply, with full details, to General Manager, BOX No. E8698, "The Engineer." A

**CADBURY BROTHERS LTD.**

have a vacancy for a

**MACHINE DESIGNER**

With experience in the design of special purpose machinery. Applicants should preferably have gained the Higher National Certificate in Engineering or have similar qualifications. Some experience in the Food Industry would be an advantage. Housing accommodation available. Applications, stating age, experience, qualifications and salary, should be addressed to Chief Engineer, Cadbury Brothers, Ltd., Bournville, Birmingham.

E8704 A

**DESIGNER-ESTIMATOR** required immediately for small Drawing Office—R. G. Abercrombie and Company Limited, Alloa. Non-contributory pension scheme in operation. Experience of distillery work, bottling plant, food factory work, advantageous.—Please apply, in writing, stating age and giving details of education and experience. Technical qualifications to H.N.C. essential. Salary according to age and qualifications. E2695 A

**DEVELOPMENT ENGINEER**, 25–30 years, minimum educational qualification H.N.C., to investigate problems relating to air movement and cleaning leading to development of new plant. Interesting job with good prospects for right man. Location Surrey.—Write BOX No. E8694, "The Engineer." A

**DEVELOPMENT ENGINEER** required for well-known Engineering Company expanding existing Foundry capacity. Applicants must have experience of machine design covering mass production of small castings, plant layout and be capable of seeing projects through from drawing-board to full production, educated to H.N.C. Write, stating full details of experience and salary required.—BOX No. E2677, "The Engineer." A

**ENGINEER** required to join development laboratory for work on a wide range of industrial instruments. Applicants must hold degree or H.N.C. in Mechanical Engineering or Physics, and have previous development experience, preferably in the Instrument Industry. Housing available.—Please write, giving full details to the Chief Design and Development Engineer, K.D.G. Instruments, Ltd., Manor Royal, Crawley, Sussex. E8653 A

**ENGINEER SURVEYORS.**—Insurance Company has vacancies in various parts of U.K. for Engineer Surveyors for inspection of Boiler and Pressure Plant. Applicants not over 38 years, must have 1st Class M.O.T. Certificate with Steam Endorsement or equivalent qualifications. Salary according to E.S.A. scale, starting at £800 per annum. Non-contributory pension and other benefits.—Write, BOX E886, L.P.E., Romano House, 399/401, Strand, London, W.C.2. E8705 A

**ENGINEERING ASSISTANT** required for work in Southampton Docks at a starting salary of £943 per annum to a maximum of £985 per annum. Applicants should preferably have had experience in the design of dockside or similar structures and buildings in steel and/or plain and reinforced concrete.—Applications, stating age, qualifications, &c., should be addressed to Chief Docks Engineer, British Transport Commission, Herbert Walker Avenue, New Docks, Southampton. E8642 A

**ENGINEERING DRAUGHTSMAN**

Young Mechanical/Structural Engineer Draughtsman, age 20 to 25, required for Head Office Staff of Large Food Manufacturing Company. Successful applicant will work for Chief Engineering Consultant and Chief Engineer. Preference will be given to candidates who have attained H.N.C. or equivalent standard. Salary according to age and experience.—Write, BOX No. E8711, "The Engineer." A

**ENGINEERS** with considerable experience of construction of pipeline, pump stations and tank farms, required by important firm for Middle East.—Write to BOX No. 3132, c/o Charles Barker and Son Limited, Gateway House, London, E.C.4. E8577 A

**ENGINEERING, PHYSICS AND SCIENCE GRADUATES OR EQUIVALENTS** required for new appointments involving research, design and development work on (1) Dynamic behaviour of machine tools and problems associated with automatic control; (2) Press working processes, cold extrusion and other new techniques for the forming of metals; (3) Machining processes; initially work will be concerned with the appraisal of new machining developments or studies of machining costs on a comprehensive scale; (4) Mechanical engineering equipment including special machine tools, presses, mechanisms, test rigs, &c. Successful candidates will be expected to take complete responsibility for projects from conception to completion. Capacity for creative thinking and initiative are important. The conditions of employment are attractive and there are excellent prospects for advancement. Superannuation scheme. Removal expenses paid.—Send full details in confidence to the Secretary (R.635), Production Engineering Research Association, Melton Mowbray, Leics. E8697 A

**ERECTION MECHANICAL PLANT ENGINEER**

to be responsible for the inspection and maintenance of all mechanical erection plant. This job involves travelling throughout the country. Engineers aged 28 to 35 with at least Grad. I.Mech.E. should apply in detail, mentioning this paper and quoting the reference number 4/60, to the Staff Officer,

WHESSOE LIMITED,
Darlington.

E8708 A

**ESTIMATOR** required by a Company engaged in the manufacture of light engineering mechanism.—Apply by letter giving full details to: Personnel Manager, Teleflex Products, Ltd., Basildon, Essex. E8699 A

**GENERAL MANAGER** required for old-established firm of Boiler Setting Engineers, Furnace Contractors, &c. The successful applicant must be fully experienced in all aspects of this trade and have held a similar appointment. Salary payable will not be less than £2000 per annum.—BOX No. E2698, "The Engineer." A

**HEATING & VENTILATING ENGINEER,** experienced all types ventilating and heating, capable taking complete charge of contracts. Good salary, pension scheme and L.V.—Write in confidence, giving age, experience and salary expected to The Secretary, Carrier-Ross Engineering Co. Ltd., 22A, Cavendish Square, London, W.1. E2685 A

**HEAT TRANSFER ENGINEER,** A.M.I.Mech.E. or H.N.C., for work on Extended Surface and Plain Tube Heat Exchangers Factory in West Sussex. Prospects excellent in rapidly developing company. Must be willing to travel.—BOX No. E8613, "The Engineer." A

**JACKSON BROS. (OF KNOTTINGLEY), LTD.**

require a DRAUGHTSMAN for work in modern, glass-producing factory on bottle-mould design. Experience in this class of work is desirable, but not essential. Canteen facilities.—Apply Personnel Officer, Jackson Bros. (of Knottingley), Ltd., Headlands Lane, Knottingley, Yorkshire.

E8484 A

**JUNIOR MECHANICAL ENGINEER OR DRAUGHTSMAN** with experience in chemical or similar engineering, required now by Arthur Guinness Son & Co. (Dublin) Limited, St. James's Gate, Dublin: age limit 26; must have H.N.C. or equivalent in engineering, good practical apprenticeship, and at least one year's drawing office experience on process plant and general engineering. Starting salary in range £640 to £970 p.a., according to age and qualifications with annual advances. Substantial amenities and excellent prospects for progressive man. Reply to Chief Engineer with particulars of age, education, training, and experience, in that order. Expenses paid if selected for interview. E8678 A

**LEADING PETROLEUM COMPANY** have vacancies in the U.K. for qualified ENGINEERS. Candidates should have had thorough training in workshops and possess either Corporate Membership of the Institutions of Civil or Mechanical Engineers or have passed parts A and B of one of these Institutions' examinations or have qualifications entitling them to exemption from such examinations. Experience on pumps and pipelines or building construction would be advantageous. Excellent conditions of employment and starting salary appropriate to qualifications and experience. Apply, giving full details of age, qualifications and experience. (Replies can only be sent to those selected for interview).—BOX No. E8520, "The Engineer." A

**PRODUCTION ENGINEER**

Large engineering firm in Glasgow, engaged in medium-heavy engineering, requires a Production Engineer to take charge of established department responsible for Methods, Planning of Work, Jig and Tool Design, and Rate-fixing. This is an important post requiring wide knowledge of modern engineering practice and offering considerable scope to successful applicant. Initial salary commensurate with experience. Contributory superannuation scheme.—Details of qualifications, experience and salary expected, to BOX No. 1411, Wm. Porteous and Co., Glasgow. E8607 A

**PHILIPS ELECTRICAL LTD.** (Medical X-Ray Division), 45, Nightingale Lane, Balham, S.W.12. A vacancy has arisen in this Company for an ENGINEER to assist in the development of X-Ray and similar equipment. The work is both mechanical and electrical. Minimum qualifications Higher National Certificate.—Applications should be sent to the Personnel Officer at the above address. E8669 A

**PILKINGTON BROTHERS LIMITED** have vacancies for FURNACE DESIGN DRAUGHTSMEN. Experience in the design of glass furnaces is an advantage, but not essential.

Applications stating age and experience should be addressed to Group Staff Department, Pilkington Brothers Limited, Grove Street, St. Helens, Lancashire.

E8665 A

**PROFESSIONAL ENGINEER**

is required at

**A.E.R.E., HARWELL**

to join a team engaged in the design, development and manufacture of nuclear reactor control elements, and the associated electrical control and position indicating equipment.

Applicants should have served a recognised engineering apprenticeship or equivalent, and should have experience in the light electro-mechanical engineering field. An Engineering degree or equivalent would be an advantage.

Salary: £1370–£1825 p.a.

Housing and Superannuation schemes.

Send postcard for details to Group Recruitment Officer (1550/4), U.K.A.E.A., A.E.R.E., Harwell, Didcot, Berks.

E8635 A

**RESEARCH AND DEVELOPMENT ENGINEER**

required

for work on the

**COMBUSTION OF LIQUID FUELS**

This position offers the successful candidate outstanding opportunities to carry out work, from fundamental research to commercial development, in the field of oil burning, in the newly-formed Research Department of one of the pioneer companies of this Industry.

Applicants should have a degree in Mechanical Engineering or equivalent qualifications. Experience either in combustion or aerodynamics is desirable but consideration will be given to candidates without this experience who are otherwise suitable.

The Company operates a contributory superannuation fund and a life assurance scheme.

Applications, which will be treated in strict confidence, should include details of age, education, experience and salary required, and be addressed to BOX No. E8575, "The Engineer."

**RICHARD SUTCLIFFE LIMITED**
**MECHANICAL HANDLING SPECIALISTS**
**REQUIRE**
**PROJECT ENGINEERS**

Applications are invited from men who are approximately 30 to 40 years of age who have passed Higher National Certificate in Mechanical Engineering and preferably with some experience in structural work.

The persons appointed will be responsible for the preparation of schemes and quotations, for dealing with all contract formalities and for customer liaison.

The position calls for competent Engineers with drive and initiative, capable of taking responsibility and of co-operating with other people in seeing a contract through, from start to finish.

Good salaries will be paid to the persons with the necessary qualifications and experience. The posts are pensionable.

Applications, giving full details of past experience, should be addressed to the Personnel Manager, Universal Works, Horbury, near Wakefield.

E8701 A

**RICHARD SUTCLIFFE LIMITED**
**MECHANICAL HANDLING SPECIALISTS**
**DISTRICT TECHNICAL MANAGER**

For over fifty years we have been supplying bulk materials handling equipment to the coal and other industries.

We now invite applications for a District Technical Manager covering the counties of Durham, Northumberland, Cumberland, Westmorland and industrial Tees-side in North Yorkshire.

The District Technical Manager will be responsible for all aspects of the Company's business in his district. In particular, he will be responsible for seeking enquiries and obtaining orders for the whole range of Sutcliffe products, for representing the customers' interests during design, manufacture and installation of equipment, and for ensuring, in co-operation with Head Office, first-class after-sales service. The person appointed will be between 30 and 40 years of age, with a background of both mining and mechanical engineering. Preferably he will have had previous selling experience.

The position calls for a person of above average ability with integrity, enthusiasm, energy and perseverance under competitive conditions. Given these qualities, the opportunities are excellent.

The commencing salary will be dependent upon qualifications and experience, but will not be less than £1500 per annum, plus a commission. Reasonable travelling and other expenses will be paid and if necessary a Company car can be provided.

The position is pensionable.

Applications in writing, should be addressed to the Sales Director, Richard Sutcliffe Limited, Horbury, Wakefield, Yorkshire.

E8702 A

Classified Advts. continued on page 108


## BOOKS and PUBLICATIONS

**PITMAN TECHNICAL BOOKS**

*FROM ALL BOOKSELLERS*

Parker St., Kingsway, London, WC2

**FUNCTIONS OF COMPLEX VARIABLES**

By Philip Franklin. This book is outstanding for its clear and precise explanation of a branch of mathematics which has often been obscured in a haze of highly abstract concepts. Logical and essentially complete, its purpose is to introduce the reader to the general properties of an analytical function of a single complex variable. 25/- net.

**SURVEYING**

By A. Bannister, M.C., B.Sc., etc., and E. S. Raymond, B.Sc., etc. A new textbook for the examinations of the H.N.C. and Diploma in Civil and Structural Engineering and in Building; I.C.E. Part II; R.I.C.S.; Dip. Tech. and Degrees in Engineering. It provides a direct approach to the subject and covers modern instruments and techniques. Engineering Degree Series. 45/- net.

To be published soon

**ENCYCLOPEDIC DICTIONARY OF ELECTRONICS AND NUCLEAR ENGINEERING**

By Robert I. Sarbacher, Sc.D., etc. A giant new alphabetical reference work containing all the modern terms and definitions, equipments, elements, components and systems. Over 1,400 pages and a million words, form an inexhaustible compilation of the latest scientific information. £8 net.

Enter No. 1071 on reply card

*"A complete library in two volumes . . ."*

**KEMPE'S** ENGINEERS YEAR-BOOK

*Edited under the direction of the Editor of "The Engineer"*

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*from technical booksellers or direct from the publishers*

**Kempe's Engineers Year-Book**, 28 Essex Street, Strand, London, W.C.2

*Telephone: CENtral 6565*

Enter No. 1072 on reply card

## SITUATIONS VACANT

**SALES ENGINEER,** resident Sheffield area, to represent South London company manufacturing air treatment and water cooling plants. Knowledge of the products and their applications essential.—Write BOX No. E8695, "The Engineer." A

**SENIOR DRAUGHTSMAN.**—May and Baker, Ltd., Dagenham, Essex, require a Senior Draughtsman with experience in the design and layout of chemical or similar plant installations. Applicants should have technical qualifications to Ordinary National Certificate level or higher. Salaries are reviewed annually. There is a pension fund and life assurance scheme in operation. Excellent canteen and sports facilities.—Apply initially in writing to the Personnel Officer, quoting Reference No. 19/60. E8709 A

**SENIOR PROJECT DRAUGHTSMAN** required for Mechanical Handling Plants. Applicants must be able to lay out schemes. Experience in Estimating an advantage but not essential. Good prospects.—W. W. Brown & Partners, Ltd., 72, Newman Street, London, W.1. E2660 A

**STEWARTS AND LLOYDS, LIMITED**
require a
**METHODS ENGINEER**

to take charge of the Methods Department at their TOLLCROSS STEEL FOUNDRY near GLASGOW.

Applicants should preferably have worked with both alloy and plain carbon steel castings, in the weight range up to 6 tons, but more important is a thorough practical knowledge of modern steel foundry methoding.

Written applications, giving full particulars of age, education and experience, should be sent to the Manager, Personnel Services, Clyde Tube Works, Coatbridge, Lanarkshire.

E8680 A

**TECHNICAL ENGINEERING WRITER**
(Age 28–35 years)

is required by a large firm of component manufacturers in the Midlands dealing with the Automobile, Aircraft and General Engineering Industries. Must be a qualified engineer with journalistic experience, capable of producing technical descriptions of products and installations from information acquired from Drawing and Design Offices.

Applications in writing, stating age, experience, qualifications and salary to BOX No. E8662, "The Engineer."

Our Staff have already been notified of this vacancy.

A

**THE MANCHESTER SHIP CANAL COMPANY**

The Manchester Ship Canal Company invite applications for the appointment of ASSISTANT CIVIL ENGINEERS and DESIGN ENGINEERS on the established staff of the Chief Engineer. Scale of salaries : £805 at age 25, rising by annual increments to £1250 at 38, with prospects of promotion to higher grades at salaries up to £1720.

Candidates should be Corporate Members of the Institution of Civil Engineers or hold equivalent qualifications, and should have experience in design, specifications, construction and maintenance of Civil Engineering Works. Harbour and dock experience is preferable but not essential.

Successful applicants will require to become members of the Company's Contributory Superannuation Scheme.

Applications, stating age, qualifications and experience, should be addressed to the Chief Engineer, The Manchester Ship Canal Company, Ship Canal House, King Street, Manchester, 2, not later than 13th February, 1960.

E8560 A

**WANTED BY EASTERN CANADIAN SHIPYARD.** SUPERINTENDENT ENGINEER to take control of Machine Shop, Pipe Fitting Shop, Fitters and Boilermakers. Applicants should have a good knowledge of Marine Engineering, both Steam and Diesel, served a recognised apprenticeship and hold a first class M.O.T. certificate. Knowledge of French an advantage although not essential. Applicants will be interviewed during March, 1960.—BOX No. E8667, "The Engineer." A

**WANTED, FIRST-CLASS SENIOR DESIGN DRAUGHTSMAN** for firm of General Engineers in Bristol. Good knowledge of general engineering, with particular reference to pressure vessels and stainless steel fabrication. This will be a well-paid position for the top-class man.—BOX No. E164, "The Engineer." A

**WORKS MANAGER** with knowledge of tube manufacture. Must have wide experience in practical and executive appointments, held similar positions and be a first-class administrator. Substantial salary will be paid to man with necessary qualifications, and future prospects are excellent.—Apply in confidence to the Managing Director, The Phoenix Steel Tube Co., Ltd., Phoenix Street, West Bromwich. E8644 A

**YOUNG ENGINEER** required as Boiler Sales representative for London Office. Training will be given in the Lincoln Works before taking up the London post. Age about 30. Experience on boilers or combustion equipment essential ; adaptable, enthusiastic. Salary will reflect experience and knowledge, and there is a generous pension scheme. —Apply Staff Manager, Ruston & Hornsby, Ltd., Waterside South, Lincoln. E8652 A

**YOUNG SALES ENGINEER** required by Importers of Continental Machines for Woodworking and Plastics Industry. Previous sales experience not essential but knowledge of German advantageous.—BOX No. E2696, "The Engineer." A

## SITUATIONS VACANT

**DESIGN & DEVELOPMENT ENGINEER**

urgently required by manufacturers of metal working machine tools, punching, shearing, guillotines, &c. Old established Manchester Engineering Company. The position is permanent and progressive and a salary commensurate with experience and ability will be paid. Good conditions of service including contributory pension scheme, free life assurance. Excellent staff canteen facilities.—Apply with fullest particulars to BOX No. E8692, "The Engineer."

A

## SITUATIONS VACANT

**NUCLEAR CIVIL CONSTRUCTORS**
*require the services of*

**JUNIOR ENGINEERS**

*at their contract for the construction of*

**TRAWSFYNYDD NUCLEAR POWER STATION**
**NORTH WALES**

Applications for positions in the Field and in the Drawing Office should be addressed, with full details of previous experience and qualifications, to :

**Mr. T. J. Winter, Business Manager,**
**NUCLEAR CIVIL CONSTRUCTORS,**
**NUCLEAR POWER STATION,**
**TRAWSFYNYDD, MERIONETHSHIRE.**

E8688 A

## SITUATIONS VACANT

**BRITISH CONSTRUCTIONAL STEELWORK ASSOCIATION**

Applications are invited for appointments to the DEVELOPMENT STAFF and to the BRIDGE DEPARTMENT.

Candidates should be young men with some experience in the design and detailing of steel frame buildings with knowledge of B.S.449 or with experience in the design of steel bridges with knowledge of B.S.153. Five-day week and luncheon vouchers. Admission to non-contributory pension scheme after qualifying period.

Apply in confidence to the Technical Adviser, British Constructional Steelwork Association, Artillery House, Artillery Row, London, S.W.1, giving fullest details with salary required.

E8675 A

**FISONS FERTILIZERS LIMITED**
**Harvest House, Felixstowe, Suffolk**

require the services of a

**CIVIL ENGINEER**

for their Head Office Engineering Section. The Engineering Offices are located at Felixstowe but applicants should be prepared to visit Works throughout the United Kingdom in the course of duties.

Applicants should hold an Engineering Degree and/or Corporate Membership of the Institution of Civil Engineers, coupled with at least 5 years' industrial experience, including a minimum of 2 years on site works. The applicant should be capable of general design work in reinforced concrete and/or structural steel work and of supervision of preparation of contract documents, specifications in connection with civil engineering and building projects associated with fertilizer and chemical plants. Preferred age group 30–40 years.

The Company operates a Pension Scheme which, for married staff, includes provision for widows and dependent children.

Applications, with full particulars, to Personnel Manager (JU4), Fisons Fertilizers Limited, Harvest House, Felixstowe, Suffolk.

E8672 A

**FOSTER WHEELER**
require
**PRODUCTION MANAGER**
for
**NITROGEN FERTILIZER FACTORY**

New nitrogen fertilizer plant in South Persia needs an experienced Engineer to supervise operation of ammonia, nitric acid and urea for about two years after one year's preparation in Europe. Age : under 50 years preferred. Graduate engineer preferred with petroleum refinery or chemical plant experience. Conversant with handling of labour. Applicants should write, giving résumé of their careers to :

Andre M. ROOS,
c/o FOSTER WHEELER FRANCAISE
31, rue des Bourdonnais,
PARIS, 1.

E8685 A

**THE GENERAL ELECTRIC COMPANY LIMITED**

**ATOMIC ENERGY DIVISION**

invite applications from the following for experimental and development work in connection with the design and construction of civil and nuclear power stations :—

**UNIVERSITY GRADUATES (REF. DWB/15)**

Preferably under 30 years of age, interested in the basic design and analysis of complex steel structures, stress analysis of shells, evaluation of temperature stress distributions, mechanical vibrations and pipework calculations. Although previous experience of this type of work is not essential, the successful candidate should have an honours degree in mechanical or civil engineering.

**YOUNG MECHANICAL ENGINEER (REF. DWB/16)**

To join a team engaged on experimental and development work on mechanical engineering problems. Qualifications required are an engineering degree or equivalent, D.O. and workshop experience, and an active versatile mind not constrained to conventional thinking.

**LABORATORY ASSISTANTS (REF. DWB/17)**

For the Instrument and Electrical Section. Duties will involve the development and testing of electro-mechanical and electronic measuring and control devices ; maintenance of electrical measuring, controlling and recording instruments ; location and rectification of faults on a wide variety of electronic instruments. Applicants should have had experience in at least one of these fields, possess their O.N.C. in Electrical Engineering and be continuing their studies towards H.N.C.

Applications, with a brief résumé of qualifications and experience should be sent to the Personnel Manager, The General Electric Company Limited, Erith, Kent, quoting the appropriate reference.

E8681 A

**AUSTRALIANS**
**AUSTRALIANS**
**AUSTRALIANS**

With an Engineering Degree and practical experience in engineering production and factory management are invited to apply for a position of MANAGING DIRECTOR of a well-established and profitable engineering manufacturing company with a modern factory in Sydney.

The company is a wholly-owned subsidiary of a powerful Group with headquarters in Britain and world-wide connections. Full responsibility for the operation of the Australian subsidiary is vested in the Managing Director who has a local Board of Directors. The appointment carries a high basic salary with additional bonus calculated on profits and the use of a Company car, superannuation, and other benefits.

This is a splendid opportunity for an Australian with the qualities of management, initiative, and leadership, the qualifications of an engineer, and the experience of factory production, to secure a remunerative and responsible position in his own country.—Applications to BOX No. E8513, "The Engineer."

A

SITUATIONS VACANT

## SENIOR DRAUGHTSMEN

experienced in bulk mechanical handling or foundry work. Superannuation Scheme. Five-day week. Apply to MARCO CONVEYOR & ENGINEERING COMPANY Ltd., Lynn Road, Leytonstone, London, E.11. LEY 2254.

E8643 A

SITUATIONS VACANT

WORK STUDY

## CHIEF ENGINEER

A major Engineering Company of international repute and in the lead in its product fields, intends to widen the scope of application of measured work in certain of its plants. In consequence, it wishes to appoint a well-qualified and experienced Work Study Engineer at its largest establishment, bordering on the home counties, to head up the application of modern incentive techniques to a number of new production lines. The vacancy will provide a challenge to a first-rate engineer with substantial study experience of metal fabrication in flow production. Salary will be commensurate with experience and the post offers considerable opportunity for promotion.

Applications with full curriculum vitae including details of salaries earned, may be made in strict confidence to Box No. 3146, c/o Charles Barker & Sons Limited, Gateway House, 1, Watling Street, London, E.C.4.

E8676 A

SITUATIONS VACANT

## DESIGNER DRAUGHTSMEN

- SENIOR STRUCTURAL (STEEL)
- ARCHITECTURAL
- ELECTRICAL

Designer/Draughtsmen of the above categories are cordially invited to contact us with a view to permanent employment. Candidates must hold Higher National Certificate, or equivalent, plus five to seven years' design experience. Successful applicants will benefit from excellent salaries, first-class working conditions, attractive personnel benefits and every opportunity for promotion. Apply Personnel Manager,

**KELLOGG INTERNATIONAL CORPORATION**
7-10 CHANDOS STREET, LONDON, W.1. TEL: MUSEUM 4010

*Please quote reference 158/G*

E8674 A

## a number of DESIGN ENGINEERS

**are required,** with experience in the design and the associated calculations of Condensing, Feed Heating and De-aerating Plants for Land service Power Stations.

Applicants should have a University Degree or equivalent qualification, with specialised experience in Heat Transfer.

Salaries offered will be appropriate to experience and responsibility, and there is a contributory Pension and Life Assurance Scheme in operation.

Barrow in Furness is pleasantly situated on the coast adjacent to the Lake District. The Company has a well-appointed Sports Club and Grounds, with comprehensive recreational facilities, both social and sporting. An illustrated guide to the town and surroundings can be sent on request.

All applications should be addressed to the

**ENGINEERING TECHNICAL MANAGER,**
**VICKERS-ARMSTRONGS (ENGINEERS), LIMITED,**
**Naval Construction Works, Barrow in Furness, Lancashire.**

E8654 A

## ENGLISH ELECTRIC RUGBY

require

## ENGINEERS FOR DESIGN AND DEVELOPMENT WORK

on

## STEAM TURBINES

Engineers holding a good Honours Degree or a further Degree with, or without, previous turbine experience, are invited to discuss at a preliminary interview attractive openings which are now arising in the Steam Turbine Division at Rugby. A few vacancies also exist for men with H.N.C. (Mech.) and several years' D.O. and Design Office experience on Steam Turbines and associated plant. If you are interested, please call between 5.30 and 7.30 p.m. on WEDNESDAY, 3rd FEBRUARY, for an informal discussion at Marconi House, 336/7, Strand, London, W.C.2.

However, if unable to attend for interview, you are invited to write, giving full details of your qualifications and experience, to Dept. C.P.S., at the above address, quoting reference number E1150A.

E8661 A

**THE ASSOCIATED PORTLAND CEMENT MANUFACTURERS LIMITED**

require several

## SENIOR AND JUNIOR MECHANICAL ENGINEERING DRAUGHTSMEN

for work on plant layout schemes and details at Head Office, Westminster.

Experience in heavy machinery plant layout and mechanical handling an advantage. Applicants with H.N.C. in Mechanical Engineering preferred for Senior Posts.

The Company offers good salaries and working conditions, pension fund and profit-sharing bonus.

Replies, giving particulars of training and experience, will be treated in full confidence and should be sent to the following, marked " Personal " :—

**The Manager,**
**Central Engineering Department,**
**Associated Portland Cement Manufacturers Ltd.,**
**Portland House, Tothill Street, LONDON, S.W.1.**

E8664 A

**JOSEPH LUCAS (ELECTRICAL), LIMITED**

*There are vacancies for*

## DESIGNERS & DRAUGHTSMEN FOR LIGHTING DEPARTMENT

to work on mechanical design of a wide range of lamps for new car models. The work involves the application of pressure diecasting, pressing and plastic moulding techniques for large quantity production and some experience in one of these fields would be an advantage.

Applicants should have Higher National Certificate, but consideration will be given to men with Ordinary National Certificate and suitable experience. The posts are permanent and pensionable, and a good starting salary will be paid. Five-day week.

**Apply in writing, stating age, qualifications and experience to the Personnel Manager, JOSEPH LUCAS (ELECTRICAL), LIMITED, Great King Street, Birmingham, 19, quoting reference PM/D/373.**

E8656 A

SHELL

**THE ROYAL DUTCH/SHELL GROUP**

require

## CHEMICAL ENGINEERS

**IN HOLLAND**

for

**DESIGN, DEVELOPMENT,**

**TECHNOLOGICAL AND**

**OPERATIONAL WORK**

Applicants should possess an Honours Degree in Chemical Engineering or the equivalent professional qualification, with at least 5 years' relevant experience.

The upper age limit is 35 years.

Applications with full details to:

**SHELL INTERNATIONAL CHEMICAL COMPANY LIMITED,**
**Personnel Recruitment/H6,**
**St. Helen's Court, Gt. St. Helen's, London, E.C.3.**

E8647 A

**Classified Advts. continued on page 110**

SITUATIONS VACANT

## T.I. (GROUP SERVICES) LIMITED

(THE SERVICE COMPANY OF THE TUBE INVESTMENTS GROUP)

A number of vacancies are available in the Plant Development Department of the above company for experienced DESIGN ENGINEERS.

The work of the department includes a wide range of plant design, development of prototype machines, factory planning, progressing installation programmes, etc.

Excellent opportunities exist for promotion.

Applications are invited from men of 28–35 years of age, with experience in the design of special purpose machines and having as a minimum qualification Higher National Certificate or the equivalent. They should be sent, giving full details of qualifications, experience, present salary, etc., to the Personnel Manager, T.I. (Group Services) Limited, Rocky Lane, Aston, Birmingham, 6.

E8703 A

SITUATIONS VACANT

## THE WELLMAN SMITH OWEN ENGINEERING CORPORATION LIMITED

PARNELL HOUSE, WILTON ROAD, LONDON, S.W.1.

Consequent to long-term increased activities, we have vacancies for the following staff :—

**PROGRESS CLERKS** preferably with general engineering knowledge and experience.

**SPECIFICATION WRITERS** for Furnaces and associated steelworks equipment.

**ENGINEERING CLERKS** for general Drawing Office duties.

Training will be given to suitable applicants possessing intelligence, initiative and general knowledge.

Pension scheme, five-day week.

Apply in confidence, to :—
GENERAL MANAGER, FURNACE DIVISION.

E8700 A

SITUATIONS VACANT

## BABCOCK & WILCOX LTD.

*Nuclear Power Programme*

requires

## ENGINEERING DRAUGHTSMEN

**for Project and Contract work in their expanding Atomic Energy Department.**

A knowledge of Steam-raising Plant, similar Heavy Engineering and also of Mechanisms Engineering is desirable but not essential.

Good chances of promotion for men with initiative. Five-day week. Superannuation scheme in operation. Canteen in building. Social facilities.

*Write, giving details of age, experience, and qualifications to:*

**Assistant Secretary,**
**209, Euston Road, London, N.W.1.**

E8679 A

SITUATIONS VACANT

## MAJOR PETROLEUM COMPANY

has a vacancy in their Midland Office for a qualified ENGINEER. Candidates should have had thorough training in workshops and possess either Corporate Membership of the Institutions of Civil or Mechanical Engineers or have passed parts A and B of one of these Institutions' examinations (or have qualifications entitling them to exemption from such examinations). Experience on pumps and pipelines or building construction will be advantageous. Starting salary commensurate with qualifications and experience. Excellent pension scheme.—Apply in writing, giving full details of age, qualifications and experience to BOX No. E8684, "The Engineer."

Replies can only be sent to those selected for interview.

A

## PROCESS PIPING SYSTEM ENGINEERS

Chemical or Mechanical Engineers are required for work on the design of process and utility piping systems for oil refinery and petro-chemical plants. The work involves the preparation of engineering flow diagrams and close liaison with our Process, Instrument, Mechanical Equipment, Plant Layout and Operating groups.
Applicants should have a University Degree in either Chemical or Mechanical Engineering and also at least two years' relevant post-graduate experience in industry.
Above average salaries will be paid to men with the required qualifications. Comprehensive personnel benefits include contributory Pension Scheme, Luncheon Vouchers, excellent working conditions, Social Club etc. When overtime is worked, payment is made for hours involved.

*Please apply by letter to Personnel Manager,*

**KELLOGG INTERNATIONAL CORPORATION**

7–10, CHANDOS STREET, CAVENDISH SQUARE, LONDON, W.1. *QUOTING REFERENCE G/157.*

E8597 A

## A career with scope at SMITHS

OPPORTUNITIES EXIST AT CRICKLEWOOD FOR:—

*We are leaders in the design, development and manufacture of Motor Accessories and as such offer excellent prospects to men with the desire to progress within a large and expanding organisation.*

### SENIOR DRAWING OFFICE CHECKER

The man appointed will be responsible for checking drawings prior to large-scale production. Experience in this type of work is essential, preferably in the light precision engineering field. H.N.C. standard or equivalent qualification essential.

### DEVELOPMENT ENGINEER

This interesting and responsible post occurs in the Product Development Department, and is available to men who have had at least the past five years' continuous experience in the development of precision mechanisms for mass production. An H.N.C. in Mechanical Engineering would be a suitable qualification, although A.M.I.Mech.E. would be preferred. An apprenticeship or equivalent practical training is essential.

### DESIGNERS

We require men with new ideas and a natural urge to Design in the ever-widening and exciting field of mass-produced instruments and light mechanisms.
Suitable persons will have been engaged in design work continuously for at least the past five years in the light precision engineering industry.
An apprenticeship or equivalent is necessary, together with the essential qualification of H.N.C.

### SENIOR DRAUGHTSMEN

Senior Engineering Draughtsmen with experience of small mechanisms for mass production required in the production offices. Suitable applicants must be qualified to at least H.N.C. standard. A knowledge of press work would be an advantage.

These are Senior Posts carrying attractive salaries and monthly staff status.

### PROVING ENGINEERS

This post is open to men having experience with electrical instruments, mechanical instruments and associated equipment. Suitable candidates would be between 25/30 years of age and be qualified to at least O.N.C. standard.

*Applications will be treated in Strict Confidence.* —— *Evening Interviews can be arranged on request.*

Write to the Staff Manager, quoting reference SM.238

**S. SMITH & SONS (ENGLAND) LTD., CRICKLEWOOD, LONDON, N.W.2.**

E8687 A

SITUATIONS VACANT

A leading contracting Company engaged on the design of large Oil Refineries and Chemical Plants is seeking the services of a

## PROJECT ENGINEER

who will be responsible for the co-ordination of specialist design groups and liaison with clients.

Applicants, aged about 40, should already be in a similar position and hold either A.M.I.Mech.E. or A.M.I.Chem.E.

**Commencing salary up to £2000 p.a.**

with excellent prospects.

Please write, giving full details in confidence, to BOX No. E8645, " The Engineer."

A

SITUATIONS VACANT

## HEAT TRANSFER
AND
## ELECTROMAGNETIC STUDIES
**ENGLISH ELECTRIC**
**STAFFORD**

The Company invites applications from Engineers interested in this type of development work on rotating electrical machines. This is advanced work involving a considerable personal contribution in new ideas and initiative in the development field. Applicants should be well qualified mechanical or electrical engineers with a keen interest in one of these studies.

If you would like to visit Stafford to discuss these openings, please write giving full details to Dept. C.P.S., Marconi House, 336-7, Strand, London, W.C.2, quoting reference E1295K.

E8660 A

SITUATIONS VACANT

## WORK STUDY ENGINEER

required by

**W. H. ALLEN SONS & CO., LTD.,**

to join the Work Study Section at their

**PERSHORE WORKS**

Candidates should have a sound engineering training with experience in work measurement and deriving synthetic times for costing and incentive schemes.

Good conditions of employment with contributory pension and life assurance schemes.

Write in confidence, stating experience and qualifications, to :

THE PERSONNEL MANAGER,
ATLAS WORKS, PERSHORE, WORCS.
(quoting ref. 829/247/CA.213)

E8570 A

## ICI Experienced Graduate Engineers

**are required by**

the manufacturers of the widest range of plastics, raw materials and semi-finished products in the Commonwealth.

**THE PLASTICS DIVISION OF IMPERIAL CHEMICAL INDUSTRIES LIMITED** is now expanding its Engineering Department in order to keep pace with growing sales in home and overseas markets. Enquiries are invited from :

### MECHANICAL AND CHEMICAL ENGINEERS

**holding first or second class honours degrees with some years of industrial experience.**

The Division is looking for men of energy, initiative and proved ability. Good starting salaries will be paid immediately, and prospects for the future are excellent. The individual projects upon which candidates will be engaged vary in character and involve all types of engineering, from light precision machine work to heavy process. They include all the planning, layout and procurement associated with the design and erection of large manufacturing units. Some of the work is experimental, directed towards manufacture in new fields.

Conditions of service are good, and pension and profit-sharing schemes are in operation. For married men, temporary lodging allowances are available and assistance is given towards house purchase and removal expenses.

*Apply briefly to :*

**The Staff Manager,**
**IMPERIAL CHEMICAL INDUSTRIES LIMITED,**
**Plastics Division,**
**Black Fan Road, Welwyn Garden City, Herts.**

E8350 A

## ENGINEER

required by

**THE ATOMIC WEAPONS RESEARCH ESTABLISHMENT, ALDERMASTON, BERKSHIRE**

To work as a member of a project design team responsible for plant modifications and associated minor works services and the preparation of functional requirements, specifications and estimates.

Candidates should be corporate members of a Senior Professional Institution or have equivalent qualifications. They should have had considerable design experience over a wide range of engineering plant and services and possess the ability to supervise and control work undertaken by Consultant Staff. Knowledge of plant and buildings for handling explosives, radio-active material and chemicals would be an advantage.

**SALARY :**

£860–£1825 according to age, qualifications and experience.

Contributory Superannuation Scheme. A house, or substantial assistance with house purchase, will become available for married officers living beyond daily travelling distance.

POSTCARDS for application forms to the Senior Recruitment Officer at above address. Please quote ref. 2496/25.

E8636 A

## TWO RESEARCH AND DEVELOPMENT ENGINEERS

required by British-American Tobacco Company's Research and Development Establishment at Southampton, for interesting work on problems connected with the processing of tobacco, and manufacture of cigarettes, affording ample opportunity for personal initiative in research into new processes, plant machinery, their development and evaluation. Candidates should possess a Degree in Mechanical or Chemical Engineering, or equivalent qualifications, and good research and development experience is required. Industrial experience in the food or allied industries might be an asset. Salary will be commensurate with ability and qualifications.

Apply in writing, stating age and experience, to **Personnel Dept. (No. 11), British-American Tobacco Company, Limited, Westminster House, 7, Millbank, London, S.W.1.**

E8663 A

## IMPERIAL SMELTING

(A MEMBER OF THE CONSOLIDATED ZINC CORPORATION LIMITED)

The following engineering vacancies are currently available at the Avonmouth Works and in Group Departments on the Avonmouth Site :

**AVONMOUTH WORKS**

**Assistant Area Engineer**

Duties involve controlling work done by tradesmen and labourers on zinc blast furnace and associated plant, including provision of spares, operation of bonus schemes, and general supervision of engineering maintenance work. An apprenticeship, preferably in heavy engineering, and professional qualification or degree in Mechanical Engineering essential. Previous experience in a supervisory capacity in heavy chemical or metallurgical industry is desirable. Age limits 23-35. Ref. TE/ENG/70

**CHIEF ENGINEER**

**Engineering Assistants**

Opportunities to train for future engineering posts of responsibility exist for two young men with a university degree or Higher National Certificate in Mechanical or Chemical Engineering. Mobility is important since the persons appointed may be required to work for indefinite periods at any of the seven Works Sites. Ref. TE/ENG/71

**Group Mechanical Engineer**

One of a team of design engineers who are collectively responsible for the detail design work arising out of capital expenditure projects at any of the Corporation's Works and for following the projects through to their completion, including procurement and construction. A university degree or professional qualifications in Mechanical Engineering will be required, together with sound design experience—preferably in heavy engineering. Ref. TE/ENG/72

**Draughtsmen**

For the development of schemes and detailing of equipment to guide invitations to tender and the manufacture of plant. At least five years' experience—preferably in heavy engineering—is required and preference will be given to candidates holding N.C. or H.N.C. in Mechanical Engineering. Ref. TE/ENG/73

**IMPERIAL SMELTING PROCESSES LIMITED**

**Design Engineer**

A qualified engineer, preferably with a first class honours degree and sound experience, including design in the heavier type of engineering, is sought. Duties are to participate in the design and development of blast furnaces and ancillary plant for the Imperial Smelting Process, and in this instance, fluency in both written and spoken German is very desirable. Ref. TE/ENG/74

CZC

Applications, quoting the reference(s) of particular interest and giving brief details of qualifications and experience should be addressed to :

Personnel Manager,
**IMPERIAL SMELTING CORPORATION LIMITED,**
St. Andrew's Road, Avonmouth, Bristol.

E8650 A

Classified Advts. continued on page 112

## SITUATIONS VACANT

### BRITISH TRANSPORT DOCKS

invite applications for ENGINEERING ASSISTANT in the Dock Engineer's Office, Grimsby Docks.

Candidates should have experience in design, construction and maintenance of civil engineering works and preparation of cost estimates, contract drawings and documents. Associate Membership of one of the Engineering Institutions desirable. Salary range £1,045–£1,150 per annum. Contributory Superannuation Scheme and certain rail travel facilities.

Applications, stating age, education, training, experience and qualifications, to be sent to : Staff and Establishment Officer, British Transport Docks (T.E.), 163, Euston Road, London, N.W.1, to arrive not later than Monday, 8th February, 1960.

E8657 A

## BUSINESS OPPORTUNITIES

**REMPLOY SPONSORSHIP SCHEME.**—Send for details which show an attractive proposition to manufacturers.—Write to the Managing Director, Remploy, Ltd., 25–28, Buckingham Gate, S.W.1, or telephone VICtoria 6621 (12 lines). E155 O

## FOR HIRE

**LATTICE STEEL ERECTION MASTS** (light and heavy), 30ft. to 150ft. high, for immediate hire.—Bellman's, 21, Hobart House, Grosvenor Place, S.W.1. E103 K

**600**

**FORK LIFT TRUCKS FOR HIRE**

Modern Machines Only
Diesel & Battery/Electric
Capacities 2000 lb–18,000 lb.
Contact your nearest Depot :

**GEORGE COHEN,**

SONS & CO. LTD.
WOOD LANE, LONDON, W.12.
(Shepherds Bush 2070)
And at Stanningley (Nr. Leeds) . Kingsbury (Nr. Tamworth) . Manchester . Glasgow Swansea . Newcastle . Belfast . Sheffield Southampton . Bath

E200 K

## PATENTS

**THE PROPRIETOR** of British Patent No. 760,161, entitled "IMPROVEMENTS IN FREE PISTON INTERNAL COMBUSTION POWER HAMMER AND PERCUSSION TOOLS," offers same for Licence or otherwise to ensure its practical working in Great Britain.—Inquiries to Singer, Stern and Carlberg, Chrysler Building, New York, 17, New York, U.S.A. E8605 H

**THE PROPRIETOR** of British Patent No. 762447, entitled "A TUBE COUPLING," offers same for license or otherwise to ensure practical working in Great Britain.—Inquiries to Singer, Stern & Carlberg, 14 E. Jackson Blvd., Chicago 4, Illinois, U.S.A. E8659 H

## MISCELLANEOUS

**TIME RECORDERS.** Sales, Rentals, Service, Telephone Hop 2239.—Time Recorder Supply and Maintenance Co., Ltd., 157–159, Borough High Street, London, S.E.1. E110 I

**MOBILE LIFTING SERVICES.**—Lump sum or Hire Rate Quoted for any Lifting Work by Lorry-Mounted or Crawler Cranes, any size, any area.—TARSLAG, LTD., Rotherham 3235. E166 I

**INSPECTING ENGINEER,** Resident Birmingham. Fully conversant and experienced with Rolling Stock and Sundries, Raw Materials, Structural Steelwork, Pipework, Machine Tools, &c.

For reliable service, please apply :
87A, HOCKLEY HILL, BIRMINGHAM, 18.
Telephone : NOR. 2578.

E2697 I

**100 PER CENT. DEFERRED, 95 PER CENT. IMMEDIATE MORTGAGE.** 2nd Mortgages our speciality. Apply without obligation.—Cranbrook Mortgage Bureau, 49, Cranbrook Road, Ilford, Essex. E177 I

## AGENCIES

**ENGINEERING AGENTS AND CONSULTANTS** specialising in Machine Tools and Transmission, seek further Agencies in South Wales and West of England on Commission basis.—BOX No. E2699, "The Engineer." D

## SUB-CONTRACTING

**KELLERING AND CAM PROFILING** capacity up to 8ft. by 6ft. or 6ft. diameter.—ARMYTAGE BROS. (KNOTTINGLEY), Ltd., The Foundry, Knottingley, Yorkshire (Telephone : Knottingley 2743/4). E116 MW

## FOR SALE

**FRED WATKINS (ENGINEERING) LTD.**

Fielding 500-ton Vertical Downstroke Hydraulic Press, 42in. by 36in. platens, with pumps and motors.
Fielding 200-ton ditto, 3ft. stroke, with pumps and motors (5 available).
Fielding 100-ton ditto, 4ft. to 5ft. stroke, with pumps and motors.
Two 73ft. 4in. by 4ft. Brick Lined Kilns or Dryers, with Crofts reduction gears and motors.
Two 26ft. by 4ft. Rotary Cooler or Dryers, with reduction gear and motor.

**FRED WATKINS (ENGINEERING), LTD., COLEFORD, GLOS.** E151 G

**SOAG**

**IMMEDIATE DELIVERY**

FRORIEP

**PIT PLANER**

Model 20.000

Capacity : Max. planing length 56ft., max. planing width 15ft. Normal depth of pit (under crossrail) 13ft. with 4 toolheads—cuts in both directions. All electric drive with Ward Leonard Set—main motor a.c. 135 h.p.—push-button control stations, independent power feeds, rapid power traverse, mech. tool-lifts.

Fully reconditioned and ready for work. The ideal planer for heaviest, bulky workpieces, armour plating, &c. Available at fraction of new price.

Write for full particulars to :

**SOAG MACHINE TOOLS, LTD.,**
JUXON STREET, LAMBETH,
LONDON, S.E.11.
'Phone : Reliance 7201.
Grams : "Sotoolsag," London, S.E.11.

E8671 G

**MILWAUKEE 3H HORIZONTAL MILLING MACHINE**

Table 64in. by 13½in.; capacity 34in. by 12in. by 17in.; spindle speeds 20/1000 r.p.m.

**F. J. EDWARDS, LTD.,**
359–361, EUSTON ROAD,
LONDON, N.W.1.
Phone : EUSton 4681 and 3771.

E8683 G

**VALES PLANT REGISTER LIMITED**
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Neals NM 2-ton MOBILES, 35ft. Lattice, Ruston engine, pneumatics, 1951-52. £1100/£1250 each.
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| | | *Main Location* | *Auctioneers* |
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| February 2 | Miscellaneous stores | M.O.A. Storage Depot, Ruddington, Notts. | WALKER, WALTON & HANSON (Dept. L), Byard Lane, Bridlesmith Gate, Nottingham. (Tel.: 54272.) |
| February 10 | Machine tools and miscellaneous stores, including:— | Technical Stores Depot, Old Dalby, Leics. (Sale at Melton Mowbray.) | SHOULER & SON (Dept. L), 1, Norman Street, Melton Mowbray, Leics. (Tel.: 3081.) |
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| February 18 | Miscellaneous stores | M.O.A. Storage Depot, Rotherwas, Hereford. | RUSSELL, BALDWIN & BRIGHT, LTD. (Dept. L), 20, King Street, Hereford. (Tel.: 4366.) |
| February 25 | Vehicles and miscellaneous stores | M.O.A. Storage Depot, Bowhouse, Hurlford, Nr. Kilmarnock, Ayrshire. | DIXON & WALLACE, LTD. (Dept. L), Bank Buildings, Graham Street, Glasgow, E.1. (Tel.: Bridgeton 2447/9.) |
| March 1-2 | Machine tools and miscellaneous stores | M.O.A. Storage Depot, Byley, Nr. Middlewich, Cheshire. (Sale at Cheetham Town Hall, Manchester, 8.) | J. H. NORRIS & SON (Dept. L), 9, Albert Square, Manchester, 2. (Tel.: Blackfriars 8373.) |
| March 8 | Machine tools and miscellaneous stores | M.O.A. Storage Depot, Royal Arsenal, Woolwich, London, S.E.18. | FULLER, HORSEY, SONS & CASSELL (Dept. L), 10, Lloyd's Avenue, London, E.C.3. (Tel.: Royal 4861.) |

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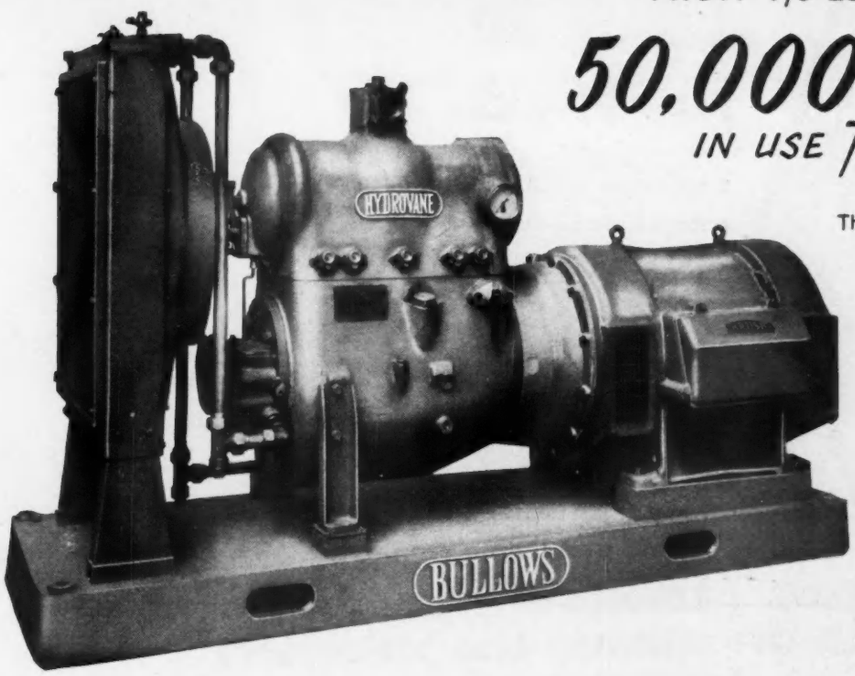


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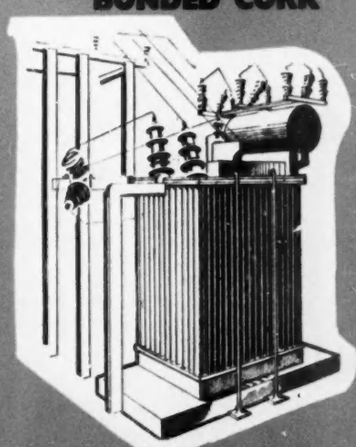

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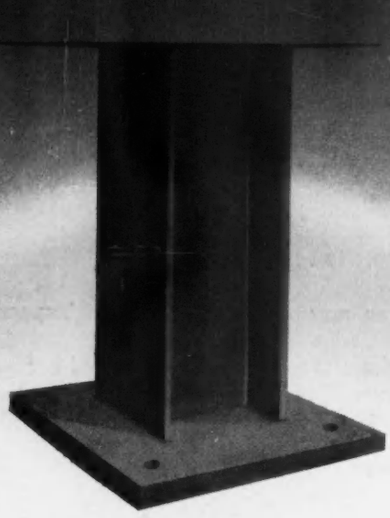

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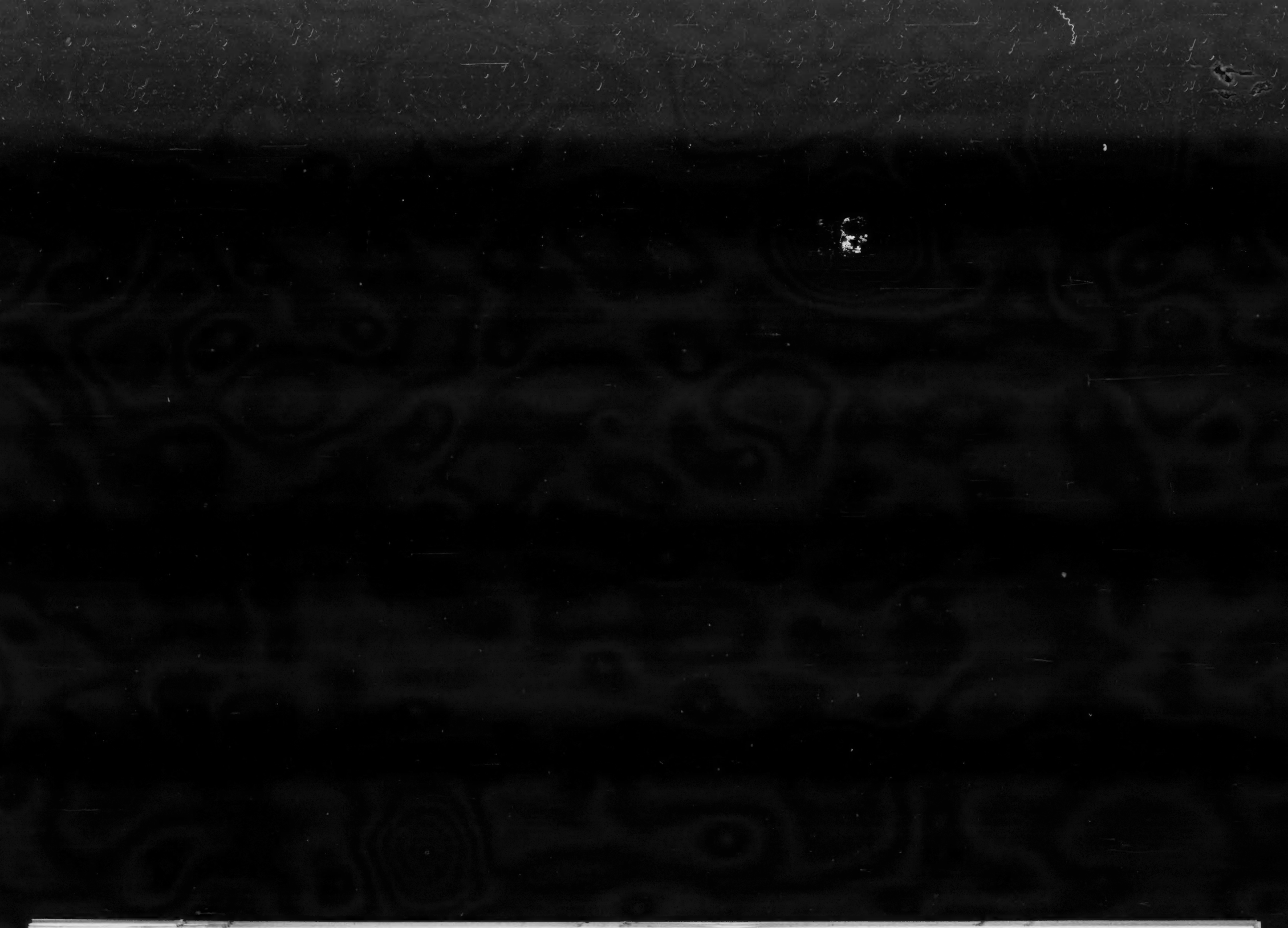
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